NEGEM

Quantifying and Deploying Responsible Negative Emissions in Climate Resilient Pathways

Public awareness and assessments of NETPs: Results of a series of cross-national public surveys

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Executive Summary

The ambition of achieving climate goals has increasingly relied on negative emission technologies and practices (NETPs) to remove past and remaining emissions and accelerate the progress of net-zero emissions (IPCC, 2022). NETPs are more likely to be implemented at scale when they are accepted by the public. Therefore, our aim of this study was to understand public acceptability of NETPs and the factors influencing public acceptability, such as perceived consequences of NETPs, perceived fairness of implementing NETPs in a country, and perceived responsibility and perceived capacity of a country to implement NETPs. In particular, we focused on afforestation and reforestation (AR) and direct air capture with carbon storage (DACCS), since AR is viewed as a nature-based solution and DACCS is a technological solution and they differ in important ways, notably the costs of implementation, efficiency of carbon removal, and the land needed to implement them (Deliverable 7.2).

This study addresses five research questions.

1. As people generally view AR more positively and as more acceptable than DACCS (e.g., Merk et al., 2023), we were interested to see whether people would still perceive AR as more positive and more acceptable if they learned about the pros and cons of both NETPs. In addition, we aim to understand to what extent people perceive the consequences of NETPs for nature and the environment, future generations, effectiveness in limiting global warming and effects on other mitigation efforts, and how these perceptions explain the differences in acceptability.
2. Perceived fairness is one of the important factors related to public acceptability of climate policy and system changes (e.g., Mitev et al., 2023). Two central factors may influence which country people consider it fair to implement NETPs: i) the country's responsibility for CO2 emissions; and ii) the country's capacity to implement NETPs. We studied to what extent people think any country is responsible to implement NETPs, and how the perception of the country's CO2 emissions and resources available to implement NETPs may influence perceived fairness and acceptability of implementing them.
3. Following the idea of the last point, we also investigated to what extent people find it fair and acceptable to implement NETPs in their own country, and how that relates to their perceptions of their country's contribution to CO2 emissions and capacity to implement NETPs.
4. We explored people's preferences towards different ways of achieving climate goals, including switching to clean energy sources, behaviour change, and the implementation of NETPs. As people might prioritise other ways to achieve climate goals than implementing NETPs, this question could help us clarify what pathways the public prefers.
5. Finally, we explored whether and how much the public wants to be engaged in making decisions about NETPs. Since involving the public in decision-making could increase acceptability of the policy and system changes (e.g., Liu et al., 2021), understanding to what extent people prefer to participate in decision-making about NETPs would be valuable for future implementation at scale.

A leading European market research firm, Ipsos, was recruited to carry out the survey and to ensure the representativeness of the national sample was achieved. In total, 6,818 participants in six European countries (i.e., Germany, Spain, Finland, Lithuania, The Netherlands, and Poland) filled out an online questionnaire, roughly 1,000 participants in each country. The countries were selected to have a good distribution across western, southern, northern, and central/eastern parts of Europe and to represent countries with different CDR targets based on their levels of cumulative GHG emissions and GDP per capita (Deliverable 4.3). We also considered the land area of the country to represent different aspects of capacity to implement NETPs. Representative samples of the national populations were achieved in terms of age, gender, education and region (with no more than ± 5% of deviation).

Key conclusions:

1. Across countries, AR was perceived as more acceptable and having more positive consequences (i.e., for nature and the environment, future generations, effectiveness in limiting global warming, and effects on other mitigation efforts) compared to DACCS. The results were rather similar across the six countries. Overall, people were rather positive about AR and quite neutral about DACCS, with no large division between opponents or supporters.
2. The more positively people evaluated the consequences of AR and DACCS, the more acceptable they found these NETPs. We found particularly strong relationships between acceptability of AR and perceived consequences on nature and the environment; for DACCS, acceptability was relatively strongly related to evaluations of all consequences (for nature, future generations, effectiveness, and effects on other mitigation measures). For both AR and DACCS, again, the results were similar across the six countries.
3. As expected, acceptability was strongly related to perceived fairness of implementing NETPs in a particular country, which in turn depended on the extent to which people consider that country responsible for CO2 emissions and capable of implementing NETPs (i.e., has the knowledge and resources to implement AR and DACCS). Specifically, participants indicated that it would be fairer and acceptable if a particular country with high CO2 emissions and sufficient knowledge and resources would implement both NETPs. We also observed that people found it fairer and more acceptable that a country with high CO2 emissions would implement NETPs even if it has less capacity, than a country with more capacity but lower CO2 emissions.
4. When it comes to the participants' own country, they again found it more acceptable and fairer to implement AR compared to DACCS. Respondents in most countries (except Finland) found their country has emitted more CO2 but has put more effort into reducing it than most other European countries. In Finland and the Netherlands, respondents thought their country is relatively more knowledgeable to implement NETPs. Lithuanian respondents believed their country is less wealthy, and Dutch respondents believed their country has less land to implement NETPs. Although people perceived their country has put more effort into reducing CO2 emissions than most European countries, this is hardly related to the acceptability of implementing both NETPs across countries. This suggests that even if people perceived their country has done quite a lot, it does not necessarily mean they think the country should not implement NETPs.
5. Overall, people thought that CO2 emissions should primarily be reduced by producing more renewable energy (37%), followed by behaviour change (24%), and to a lesser extent by using nuclear energy and implementing NETPs. On average, participants indicated that about 18% of the total CO2 emissions should be reduced with NETPs.
6. Participants wanted the general public to be informed about the development of NETPs, to be able to express opinions and to co-decide with governments and experts about NETPs. Participants thought to a lesser extent that the public should decide themselves about NETPs. Respondents in Poland, Lithuania, and Spain thought more that the public should decide themselves than respondents in Finland and the Netherlands.

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Introduction

The aim of this research was to explore, across different EU countries, the levels of public support for different types of negative emission technologies and practices (NETPs), as well as the factors that determine in which countries people think it is most adequate to implement NETPs. NETPs are technologies and processes that can remove carbon dioxide from the atmosphere, and are generally seen by experts as an important element to achieve net-zero greenhouse gas emissions (Cobo et al., 2023; Fankhauser et al., 2022; also see Deliverable 5.3 and 8.1). However, some NETPs, such as direct air capture with carbon storage, have a high potential to remove high amounts of emissions, but the technology is not mature yet and mainly used at demonstration stage. One of the factors that may influence the implementation of NETPs at scale is the level of public support. So far, only few studies have explored public perceptions and acceptability of NETPs (e.g., Merk et al., 2023), yet the focus has been mostly on single countries and little is known about key factors that shape public acceptability of NETPs, and preferences for which countries should implement NETPs.

In this research, we examined how people perceive and evaluate NETPs, in particular **afforestation and reforestation (AR)**, and **direct air capture with carbon storage (DACCS)**, across different countries. AR and DACCS differ in important ways, notably the costs of implementation, the efficiency of carbon removal, and the land needed to implement them (Deliverable 7.2). Further, AR is seen as a nature-based NETPs having low environmental impacts, while DACCS is seen as a technological NETPs having high potential for long-term carbon storage but high energy demand. Initial research suggests that people perceive AR as more acceptable and evaluate it more positively than DACCS (Jobin & Siegrist, 2020; Merk et al., 2023; Wenger et al., 2021; Wolske et al., 2019; also see Deliverable 5.1). AR is generally perceived to have a lower environmental impact and less likely to create unintentional side effects than other NETPs (Jobin & Siegrist, 2020; Wenger et al., 2021; Wolske et al., 2019). However, in previous research, participants might not fully take into account some possible disadvantages of AR (such as CO_2 leakage due to wildfire and taking a lot of land, which can no longer be used for other purposes, such as growing food; see Jobin & Siegrist, 2020), nor the possible advantages of DACCS (such as taking relatively little land and the capacity to store a lot of CO_2 for a long period of time; see Wolske et al., 2019). We were interested to see whether after providing information on the consequences of AR and DACCS participants would still perceive AR more positively and as more acceptable than DACCS, including their broader consequences for nature and the environment, future generations, effectiveness in limiting global warming and effects on other mitigation efforts.

Perceived fairness is one of the important factors highly related to public acceptability of climate policy and system changes (Bergquist et al., 2022; Mitev et al., 2023). Perceived fairness may also explain public acceptability of NETPs. Based on literatures in philosophy and political science (Deutsch, 1975; Rawls, 1971; Sovacool et al., 2022), we distinguished two central factors that may influence in which country people consider it fair to implement NETPs: i) country's **responsibility for CO_2 emissions**; ii) country's **capacity to implement NETPs**. These principles have formed the foundation of fair allocation of carbon removal targets (Fyson et al., 2020; Höhne et al., 2014; Pozo et al., 2020; see also Deliverable 4.3). Our aim was to study whether and to what extent these principles play a role in fairness judgements among the general public. While a few studies explored to what extent perceived responsibility and perceived capacity of a country affect perceived fairness and acceptability of policies and system changes in general (Hammar & Jagers, 2007; Klebl & Jetten, 2023; Klinsky et al., 2012), no studies have specifically tested this for NETPs. New to the literature, we studied to what extent people think any country should be implementing NETPs in the first place, and how the perception of the country's CO_2 emissions and resources available to implement NETPs may influence perceived fairness and acceptability of implementing them. Specifically, we first presented a hypothetical country description, where

we experimentally varied the country's emissions and resources, to see to what extent people find it fair and acceptable to implement AR and DACCS in that country. Second, we aimed to understand to what extent people find it fair and acceptable to implement NETPs in their own country, and how that relates to their perceptions of their country's contribution to CO_2 emissions and capacity to implement NETPs.

The countries included in this research are **Germany**, **Spain**, **Finland**, **Lithuania**, **The Netherlands**, and **Poland**. We selected these countries in order to have a good distribution across western, southern, northern, and central/eastern parts of Europe. As shown in Figure 1, the selected countries also represent different levels of cumulative carbon dioxide removal (CDR) targets by the year of 2100, based on responsibility principles (i.e., cumulative total GHG emissions from each country in the EU between 1750-2019; Deliverable 4.3, Gütschow et al., 2021) and capacity principles (i.e., GDP per capita (Deliverable 4.3; Pozo et al., 2020). We also consider the country's land area to represent another important aspect of the capacity of implementing NETPs (World Bank, 2020), which might be relevant for people to determine perceived capacity of a certain country to implement NETPs.

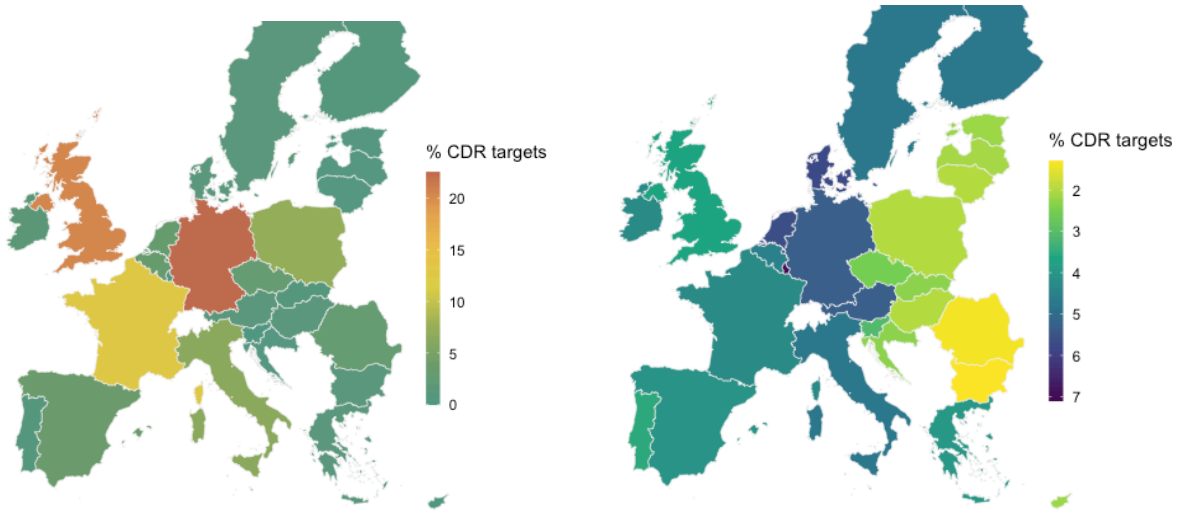


Figure 1 Shares of cumulative CDR targets by the year of 2100 allocated based on responsibility principle (left) and capacity principle (right), express in percentage
(source: Deliverable 4.3)

To give an overview of the selected country based on above criteria, Figure 2 and Figure 3 show the placing according to the dimensions of shares of cumulative CDR targets by the year 2100, based on cumulative GHG emissions between 1750-2019 and GDP per capita projections, and also the share of the total land area of EU-28. For example, Germany is allocated with higher CDR targets based on both cumulative GHG emissions and GDP per capita; Lithuania, on the bottom left, shows smaller shares of CDR targets because of lower emissions and lower GDP per capita. Finland is allocated with smaller CDR targets based on GHG emissions, but higher CDR targets based on GDP per capita. Spain, the Netherlands, and Poland have CDR targets somewhat in the middle based on their emissions, but have different levels of CDR targets if we consider GDP per capita of these countries. Figure 3 specifically shows the CDR targets allocated based on GDP per capita and how it fits with the availability of land. Spain, Germany, Poland and Finland are considered as having large land areas, but Poland is allocated with relatively lower CDR targets based on GDP per capita. Lithuania and the Netherlands both have smaller land areas, but the Netherlands has higher CDR targets because of high GDP per capita.

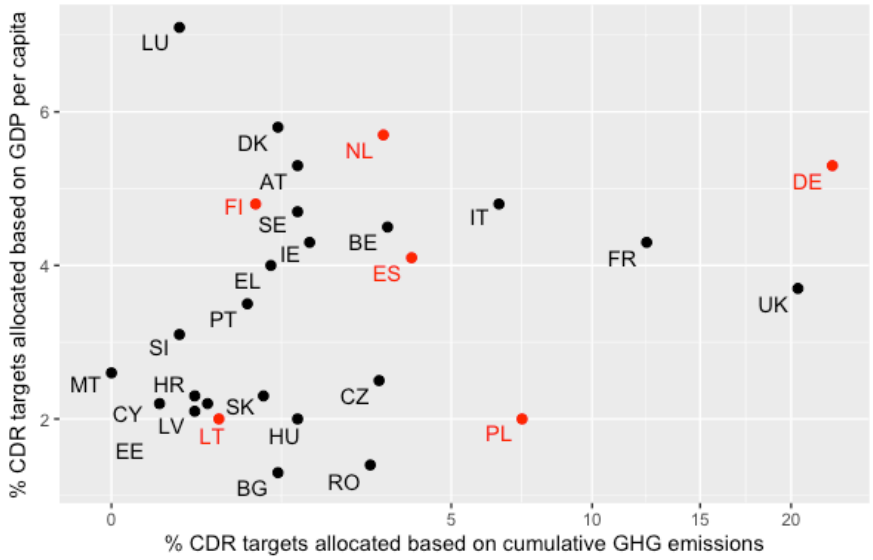


Figure 2 Cumulative CDR targets by the year 2100 within EU-28 based on cumulative GHG emissions and GDP per capita, expressed in percentage. Labels in red represent selected countries
(source: Deliverable 4.3)

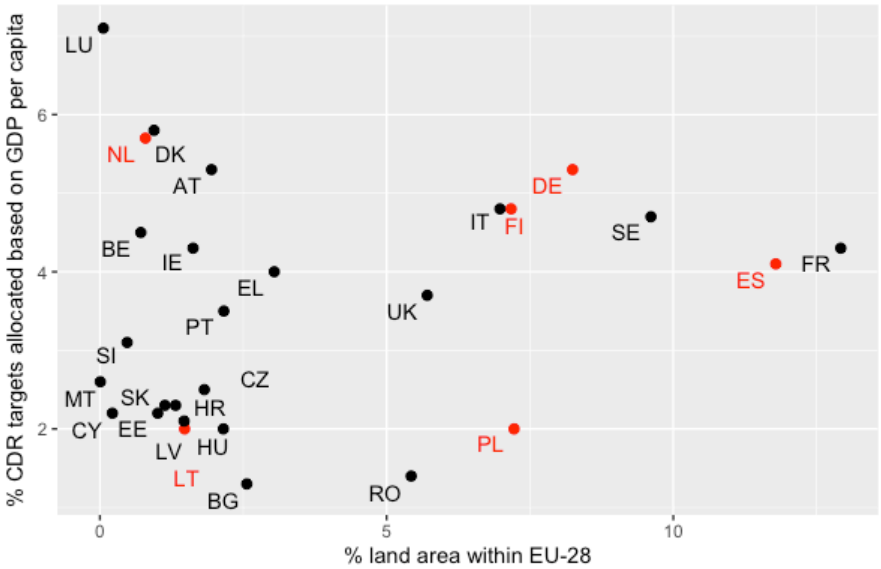


Figure 3 Shares of total land area of EU-28 and cumulative CDR targets by the year 2100 based on GDP per capita, , expressed in percentage. Labels in red represent selected countries
(Source: Deliverable 4.3 and World Bank)

Implementing NETPs is increasingly needed, since mitigation measures, such as switching to low-carbon energy sources and reductions in demand, are not deployed quickly enough to fulfil temperature targets (IPCC, 2022). Yet, people might prioritise other ways, for example, switching to clean energy sources and changing behaviour in order to reduce emissions in multiple ways, such as flying less or eating less meat. For example, studies showed higher acceptability of renewables over nuclear energy (Murakami et al., 2015; Pidgeon et al., 2008; Pidgeon & Demski, 2012), and higher preference of individual behaviour change than expanding nuclear energy (Pidgeon et al., 2008). Pidgeon et al. (2008) also suggested a lower public preference of carbon capture and storage, but the question was framed under the premise of continuing using fossil fuels, which is not the

primary focus of NEGEM project. Considering most studies rarely took NETPs in their research framework, in this study, we aimed to explore people's preference towards different ways of achieving climate goals while taking the implementation of NETPs into account.

Next to understand public perception of implementing NETPs, another important question is whether and how much the public wishes to be engaged in decision-making on NETPs. Forms of public participation in decision-making vary depending on how much influence the public has in the decision-making process (Arnstein, 1969), from informing the public (very low influence) to taking the decision on their own (very high influence). Involving the public in decision-making could increase acceptability of the policy and system changes (Liu et al., 2020; Liu et al., 2021). Communicating about the development of NETPs has been highly recommended to increase public support (Colvin et al., 2020; Honegger et al., 2017), yet this concerns only the lowest step on the "participation ladder" (Arnstein, 1969). Having the opportunity to express opinions in the decision-making process could increase people's acceptability of carbon storage policy more than no opportunity at all (Terwel et al., 2010). While some studies suggest that energy policies are more acceptable when the public has more influence on the process (Aitken et al., 2016; Reilly et al., 2016), others show that people do not necessarily prefer having full decision-making power (Banerjee & Schuitema, 2022; Ernst & Shamon, 2020; Liu et al., 2021). Since NETPs are relatively new to the public, understanding to what extent people prefer to participate in decision-making about NETPs would be valuable for future implementation at scale.

To sum up, we studied:

- Public perceptions of consequences and public acceptability of AR and DACCS.
- Public perceptions of the extent to which countries should implement AR and DACCS, based on the countries' CO_2 emissions and available resources to implement NETPs (as indicators of perceived responsibility for emissions and perceived capacity to implement NETPs).
- Public perceptions of CO_2 emissions and capacity to implement NETPs in participant's own country, and the extent to which people find it acceptable that their own country implements NETPs.
- Public perceptions of the role of NETPs in reaching climate goals, next to other mitigation measures, such as switching to renewable energy, nuclear energy, and behaviour change.
- People's preferences for how to engage the public in decision-making on NETPs.

1 Method

We recruited a reputable international market research firm, Ipsos, for survey translation and recruiting representative samples of the six selected countries. The survey was translated from English into the dominant language of each country and then checked by native speakers to ensure the meaning of questions stayed the same. All questions were presented in the dominant language of each country and optionally in English. After completing the survey, participants received credits from Ipsos, to be exchanged for gifts or gift cards worth roughly €1.50. No identifiable data was collected during the research, so the responses were anonymised. The research procedure was reviewed and granted by the Ethics Committee of the Faculty of Behavioural and Social Sciences of the University of Groningen (project number: PSY-2223-S-0182). We launched the survey at the end of August 2023 in all countries to ensure the comparability of the results and control for temporal events. The data collection lasted around two weeks. In total, 6,818 participants, across Germany, Spain, Finland, Lithuania, the Netherlands, and Poland, filled out the questionnaire.

After data quality inspection, we removed participants with more than two thirds of responses missing and respondents who filled out the survey in less than five minutes, which we assessed to be a minimal duration to complete the survey. We also removed participants with low intra-individual response variability, indicating responses with insufficient attention (Dunn et al., 2016). For example, we removed participants who used only one or two options to answer questions throughout the questionnaire, such as [5,4,5,4,5,4,5,4,5] or [3,3,3,3,4,4,4,3,3,3]. Based on these criteria, we removed 1,306 participants, and therefore 5,512 responses were included for further analysis.

Participants first read a brief introduction about this research and were asked for their consent for participation. Then, participants were asked for background information, including their age, gender, income level, education level and residential regions within the country. The distribution of age, gender, education, income for each country is shown in Table 1. For most countries, representative samples of the national populations were achieved in terms of age, gender, education and region (with no more than ± 5% of deviation). For Finland, the sample was representative based on age, gender and region, but not education; and for Lithuania, the sample was representative based on age and gender, but not education and region, which is probably due because Ipsos keeps fewer panellists in both countries. We did not check for the representativeness based on income, as most panellists did not provide this information to Ipsos. We have a slightly higher proportion of low education participants in Germany and a lower proportion of low education participants in Poland. For Lithuania, we have a relatively higher proportion of high education participants, and a lower proportion of participants from Vilnius County. For the details of the composition of the samples in the different countries, see Appendix A.

Since public awareness of NETPs is generally low (Jobin & Siegrist, 2020), we gave participants a brief introduction about climate change and why experts believe we need NETPs to remove CO_2 from the atmosphere. Then, we provided a brief description of AR and DACCS to all participants in a randomised order so as to balance out the sequential effect (i.e., either AR first DACCS second, or the other way around). Instead of asking participants' perceived risks and benefits about the NETPs, we decided to give them a short description and some pros and cons of implementing it. The descriptions are shown in Figure 4 and Figure 5. The descriptions were based on various studies (Buck, 2016; Jobin & Siegrist, 2020; see also Deliverable 7.2), and provided in lay language. We selected three pros and three cons of each NETP to avoid an unbalanced overview. Since AR and DACCS particularly differ in terms of the costs of implementation, land use and the efficiency in removing CO_2, we included information on these aspects. For AR, we also considered the advantages of nature-based solutions, that is, increasing the quality of nature and health-related outcomes; and for DACCS, we considered the advantage of enabling long-term storage, and its large energy usage as a disadvantage. For both NETPs, we included the disadvantage that there is a possibility of CO_2 leakage, as we thought people might likely think about the leakage from DACCS, but not AR. The first version of the descriptions of NETPs was shared with experts from the research team (i.e., UCAM, BELLONA, and VTT) for feedback; we revised the descriptions accordingly in the final version.

Table 1 Distribution of age, gender, education and income level in country samples

	Germany N=931	Spain N=878	Finland N=892	Lithuania N=994	Netherlands N=916	Poland N=901
Age						
18-24	7.3%	7.4%	7.6%	9.3%	8.7%	9.4%
25-34	13.2%	12.1%	16.5%	15.2%	14.3%	15.9%
35-44	14.8%	17.5%	19.7%	17.9%	14.4%	21.0%
45-54	16.4%	18.9%	14.7%	14.5%	17.6%	16.6%
55-64	31.7%	31.4%	22.9%	26.6%	21.4%	25.2%
65-74	14.4%	9.9%	16.0%	13.4%	18.2%	10.8%
75+	1.9%	2.4%	2.5%	2.4%	5.1%	0.3%
Gender						
Man	47.6%	48.2%	45.9%	49.7%	48.3%	49.4%
Woman	52.1%	51.3%	53.8%	50.2%	51.6%	50.2%
Education						
Low	22.7%	44.6%	11.0%	2.8%	27.7%	6.3%
Medium	56.4%	22.9%	48.4%	40.8%	36.4%	63.7%
High	20.5%	31.9%	38.6%	55.2%	35.5%	28.1%
Income						
Lowest 20%	21.7%	20.4%	19.8%	22.9%	14.1%	9.3%
Lower-middle	21.3%	20.0%	19.3%	28.3%	14.1%	16.6%
Middle	18.9%	19.0%	19.8%	16.5%	23.4%	16.8%
Upper-middle	18.3%	21.3%	19.1%	14.0%	16.2%	25.0%
Highest 20%	12.8%	10.4%	14.6%	8.5%	20.0%	22.9%

Figure 4 Description of AR, and the pros and cons of the measure presented in the survey

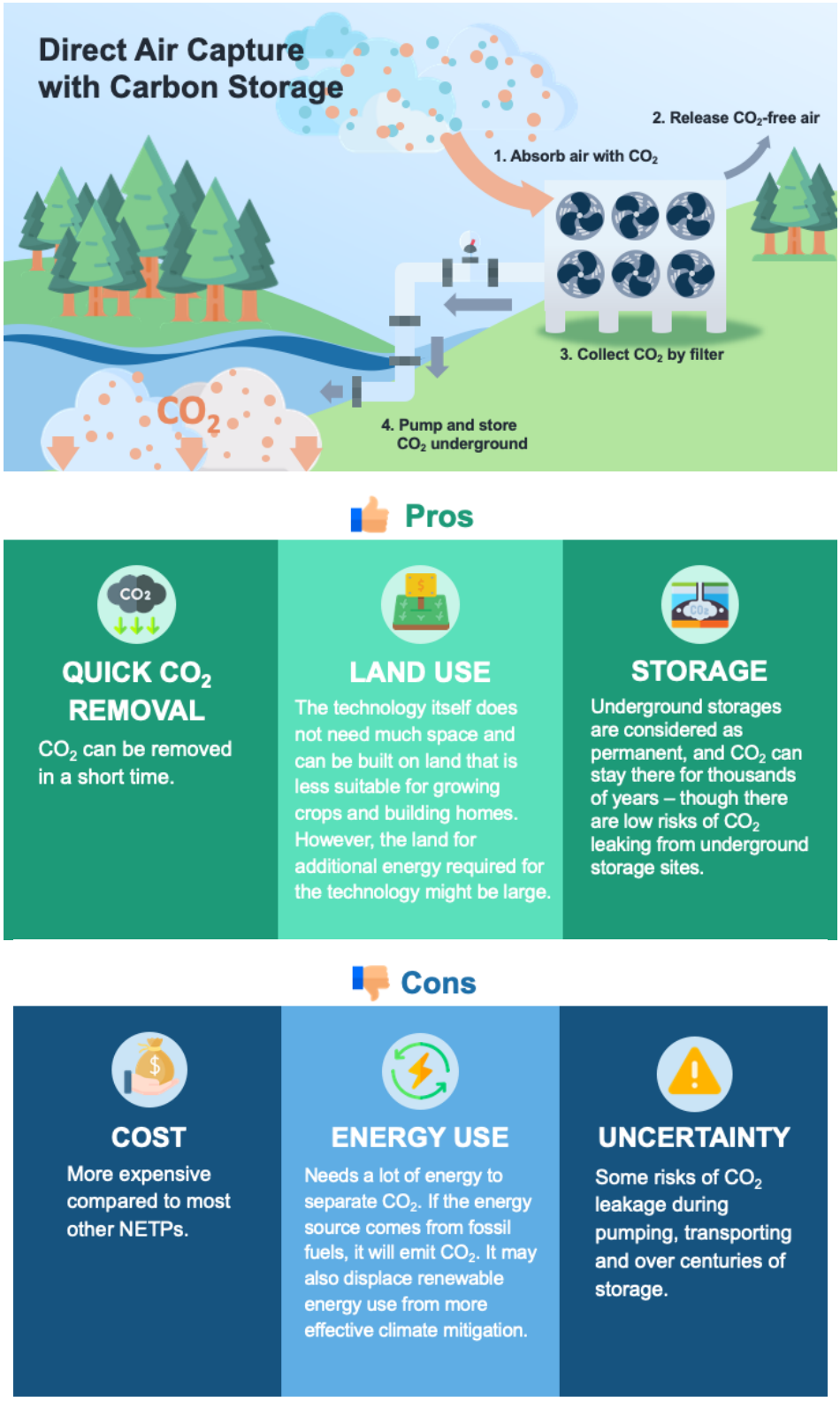


Figure 5 Description of DACCS, and the pros and cons of the measure presented in the survey

For the data analysis, we first examined the descriptive statistics of each question, including mean score (*M*) and standard deviation (*SD*) that indicates the distribution of the responses. For some questions measuring the same concept (e.g., acceptability, perceived fairness), we calculated the Cronbach's α or the Pearson's correlation coefficient (*r*) to examine whether the items indeed form a reliable scale and can thus be combined by computing an average score for further analysis. We used Pearson's correlation to see which factors were related to perceived fairness and acceptability of implementing NETPs. Positive coefficient indicates positive relationship between variables (i.e., a higher score on one variable is associated with a higher score on the other variable), while a negative coefficient indicates a negative relationship (i.e., higher score on one variable is related to a lower score on the other variable). The size of the correlation coefficients indicates the strength of the relationship, which can vary from -1 to 1, with higher positive or negative numbers indicating a stronger relationship. We used paired t-test (*t*) to examine whether two mean scores are statistically different (e.g., comparing the mean scores of acceptability of implementing AR and DACCS). The significance of the results was indicated by p-value (*p*): if $p < 0.05$, it means the mean scores are significantly different. For the experimental design in Section 2.2, we used ANOVA (*F*-test) to test whether perceived fairness and acceptability of implementing AR and DACCS were different depending on which country description people saw. The significance of the results was again indicated by p-value. Table 2 shows the overview of the statistical indicators used in this report.

Table 2 Statistical indicators

Statistical indicator	
N	Number of people included in the analysis
M	Mean score
SD	Standard deviation
Cronbach's *α*	Reliability of a scale comprising a set of items
r	Pearson's correlation coefficient, indicating the strength of the relationship between variables
p	P-value, indicating the significance level of the test results
t	Paired t-test values
F	Analysis of Variance (ANOVA) test values

2 Key findings and policy relevant messages

2.1 Perceived consequences and public acceptability of implementing AR and DACCS

2.1.1 Perceived consequences of implementing AR and DACCS

After reading the description of AR and DACCS, participants answered a series of questions regarding how they perceive the various consequences of the corresponding NETPs, and how acceptable they find implementing AR and DACCS, respectively. We aimed to ask about more general consequences than the specific consequences already included in the descriptions of NETPs to participants. The consequences include the effects on nature and the environment and future generations, respectively, as well as the effectiveness in limiting global warming and effects on other mitigation efforts.

Previous research found that AR is generally perceived to tamper less with nature than DACCS (Wolske et al., 2019), but less is known about how people perceive NETPs' impacts on future generations. Here, the question about the effects on other mitigation efforts is highly relevant, as stakeholders have already raised this concern that NETPs might replace efforts to reduce CO_2 emissions (Deliverable 8.1). Hence, participants rated four different consequences of each NETP on a 7-point scale ranging from -3 (representing a very negative consequence) to 3 (representing a very positive consequence):

"I think the implementation of [AR / DACCS] would …"

- have a negative/positive impact on the **quality of nature and the environment**;
- have a negative/positive consequence for **future generations**;
- be not effective at all/very **effective to limit global warming**;
- strongly inhibit/support other **efforts to reduce CO_2 emissions** (such as using more renewable energy, reducing fossil energy use).

Figure 6 shows that in general, AR is perceived as having more positive consequences compared to DACCS. For AR, all consequences were evaluated more positively than negatively by the majority of the respondents; for DACCS, about 50% of respondents evaluated the consequences more positively than negatively, whereas about 30% were neutral and 20% evaluated the consequences more negatively than positively. No large differences between the perceptions of different types of consequences of each NETP were observed, except that people expect AR to have very positive consequences for nature and future generations, and have slightly more reservations about its effectiveness in limiting global warming and effects on other mitigation efforts. Still, AR is generally seen as more effective and having more positive (or less negative) effects on other mitigation efforts than DACCS.

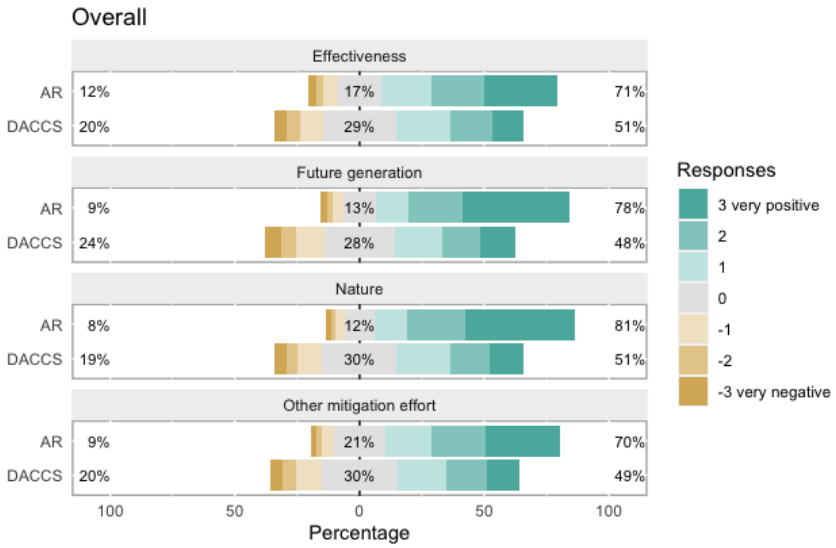


Figure 6 Perceived consequences of implementing AR and DACCS (overall sample)

As shown in Figure 7 to Figure 10, similar findings are found in each country. AR is seen as more effective, having more positive consequences for nature and future generations, and having more positive effects on other mitigation efforts than DACCS in all countries. In Finland and Poland, about 55-60% of respondents perceive DACCS as having more positive than negative consequences, which is a bit higher compared to the other countries. In contrast, around 25-30% of respondents in Germany and the Netherlands perceive DACCS as having more negative than positive consequences, which is a bit higher compared to the other countries. In Lithuania and Spain, the pattern is very similar to the overall pattern of results, but in Spain, slightly fewer respondents evaluated the consequences of AR for nature and future generation positively (around 70-75%, compared to overall 80%).

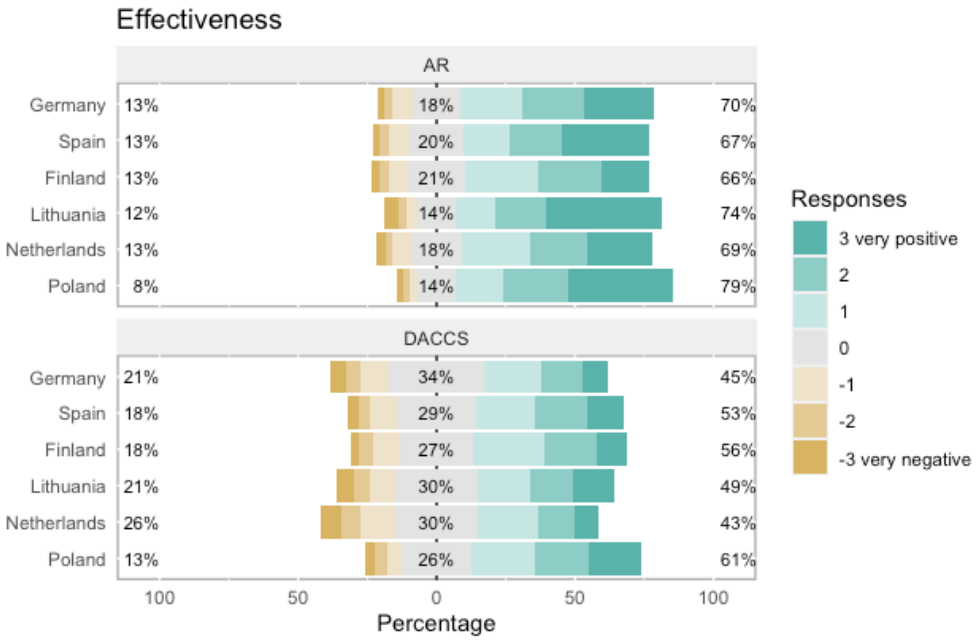


Figure 7 Perceived effectiveness of implementing AR and DACCS

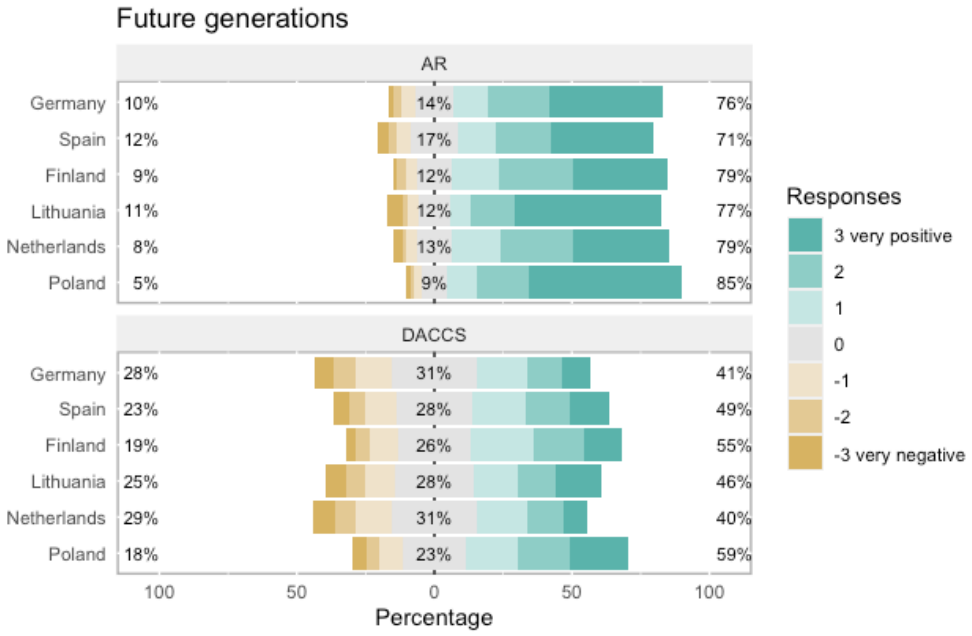


Figure 8 Perceived consequences of implementing AR and DACCS on future generations

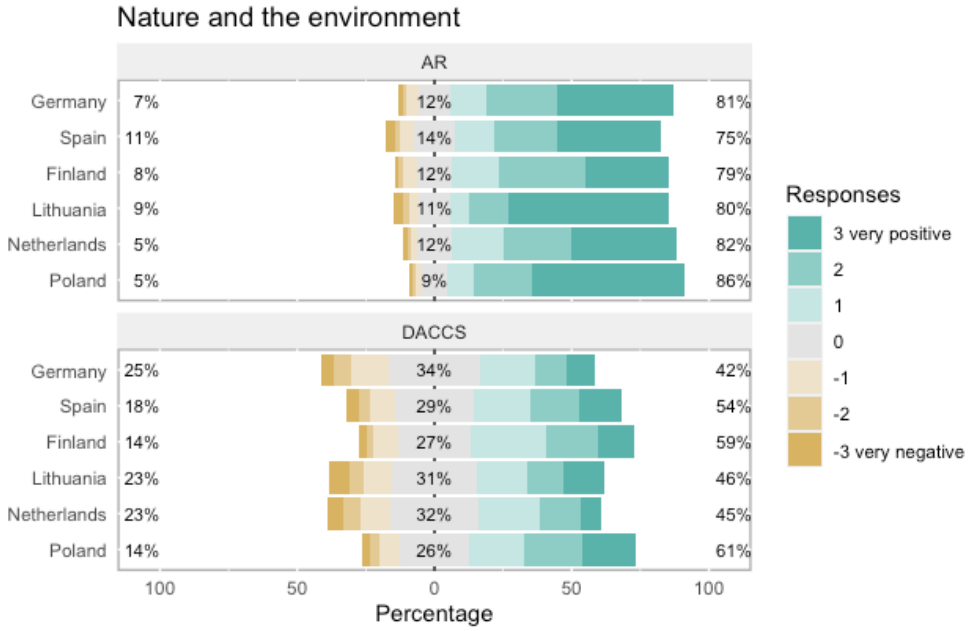


Figure 9 Perceived consequences of implementing AR and DACCS on nature and the environment

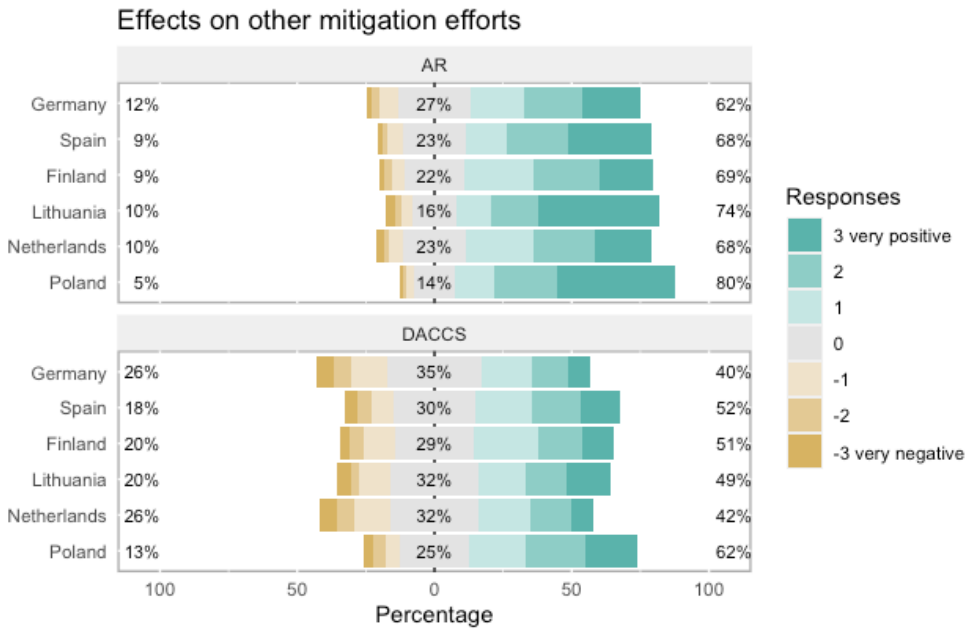


Figure 10 Perceived consequences of implementing AR and DACCS on the effects on other mitigation efforts

2.1.2 Acceptability of implementing AR and DACCS

Public acceptability of implementing AR and DACCS was evaluated with three items on a 7-point scale ranging from -3 to 3. The question was as follows:

'In general, I think the implementation of AR/DACCS is…'

- A very bad idea — A very good idea;
- Very unnecessary — Very necessary;
- Very unacceptable — Very acceptable.

The mean score of combined three acceptability items are calculated since the three items formed a reliable scale[1]. In general, people report higher acceptability of AR compared to DACCS[2]. Figure 11 shows public acceptability of implementing AR and DACCS across the entire sample. Interestingly, neither for AR nor for DACCS we found a clear division between strong opponents and supporters. In general, people evaluate AR as acceptable. For DACCS, a considerable share of respondents was neutral (around 30%) and some had more negative responses (about 20%). As shown in Figure 12 to Figure 14, similar patterns are found across countries. Acceptability of DACCS was slightly lower in Germany and in the Netherlands. Spanish respondents were more neutral than positive compared to the general sample. In Finland and Poland, acceptability was somewhat higher. In Lithuania, the patterns are very close to the overall pattern of results.

[1] Cronbach's α_{AR} = .92; Cronbach's α_{DAC} = .93.

[2] $t(5358) = 53.218$, $p < .001$; $M_{AR} = 1.90$, $SD_{AR} = 1.26$; $M_{DAC} = 0.66$, $SD_{DAC} = 1.48$.

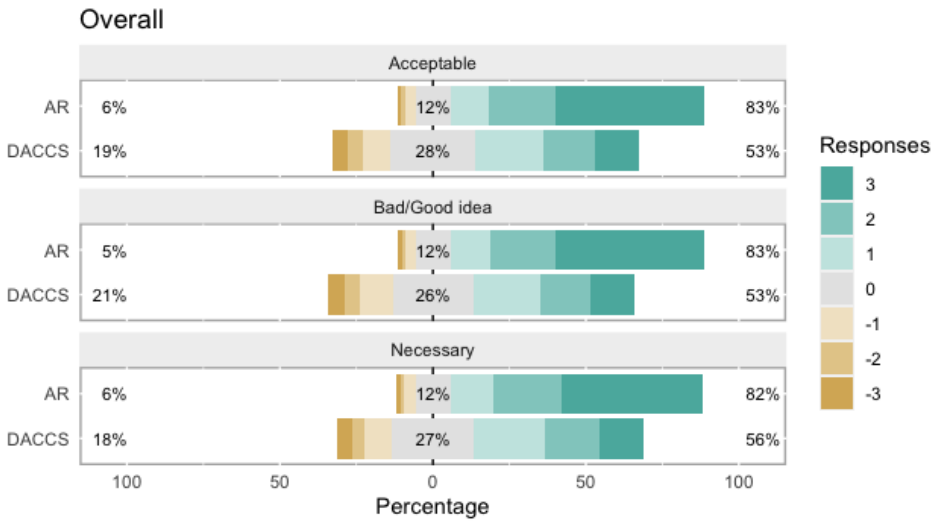


Figure 11 Acceptability of implementing AR and DACCS (overall sample)

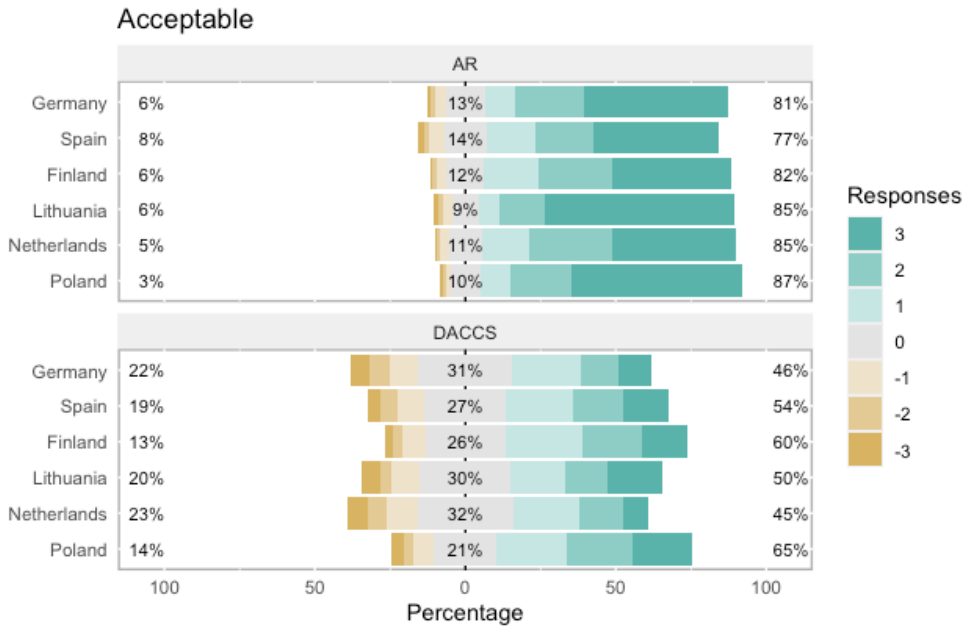


Figure 12 To what extent it is acceptable to implement AR and DACCS

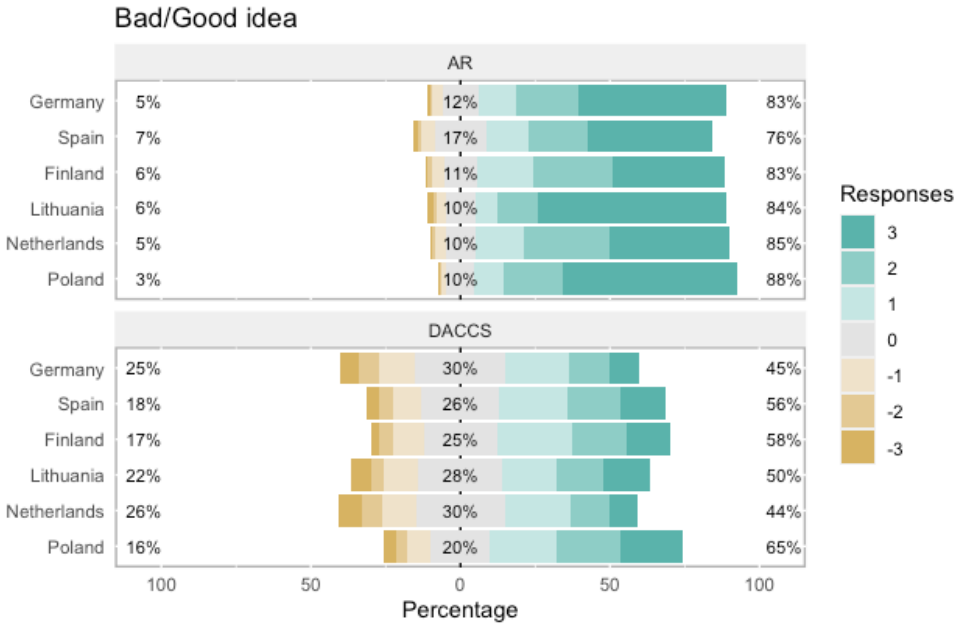


Figure 13 To what extent it is a good or bad idea to implement AR and DACCS

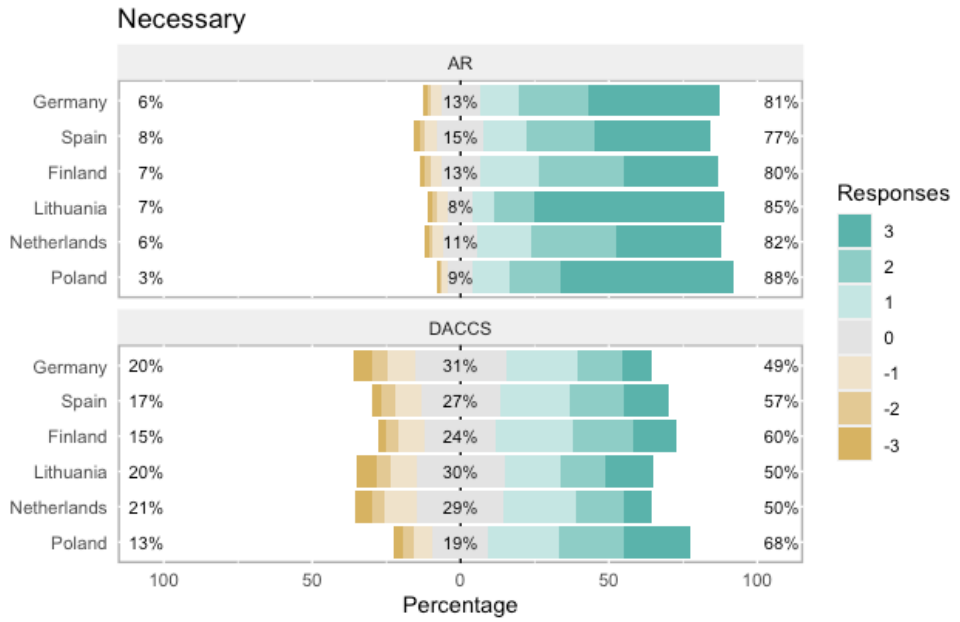


Figure 14 To what extent it is necessary to implement AR and DACCS

2.1.3 Relationships between perceived consequences and acceptability of implementing AR and DACCS

We next studied to what extent acceptability of implementing AR and DACCS was related to the evaluation of their consequences, as reflected in the bivariate correlations between acceptability and evaluation of the four consequences. Figure 15 shows the correlations between perceived consequences and acceptability of each NETPs for the entire sample. For both NETPs, acceptability is higher when people evaluate the four consequences more positively. For AR, acceptability most strongly related with perceived positive consequences for nature and

future generations, and also rather strongly with perceived effectiveness on limiting global warming and effects on other mitigation efforts[3]. For DACCS, acceptability was strongly and positively related with all perceived consequences (r > .70), with again a strong relationship between acceptability and perceived positive consequences on nature and future generations[4]. As shown in Figure 16 to Figure 21, similar patterns are found across all countries. Nature and the environment remained the key consequence that correlated most strongly with acceptability for both NETPs in all countries, with a slight exception in Spain, where the other three consequences were even more strongly positively associated with acceptability. In general, this finding is similar to previous studies that the more people perceived a CDR technology to tamper with nature, the less they support the technology (Jobin & Siegrist, 2020; Wolske et al., 2019). In Germany and the Netherlands, the correlation between acceptability of AR and the perceived effects on other mitigation efforts was slightly weaker, while in Spain the relationship is slightly stronger compared to other countries. Effectiveness in limiting global warming and effects on other mitigation efforts were consistently more strongly positively correlated with acceptability of DACCS than AR, in all countries. It is possible that people found AR as a nature-based solution acceptable anyway regardless of its effectiveness. However, people may perceive that DACCS, which is a technology-based solution, has less positive effect implications for nature and thus the legitimacy of implementing the technology may rely on other impacts, such as the effectiveness of limiting global warming and the effects on other mitigation efforts. Future research is needed to examine this further.

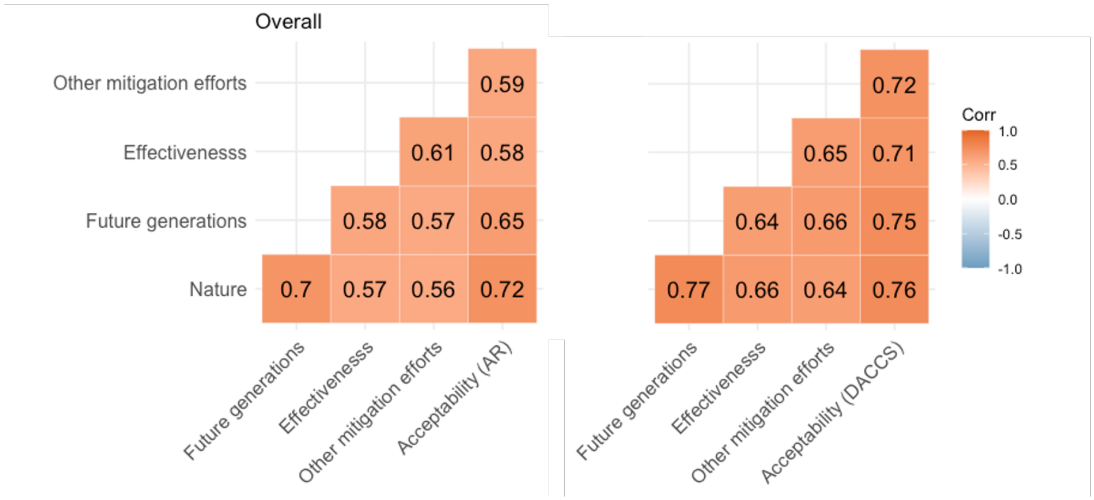


Figure 15 Correlation between perceived consequences and acceptability of implementing AR and DACCS (overall sample)

[3] r(nature) = .72; r(future generations) = .65; r(effectiveness) = .58; r(other efforts) = .59.
[4] r(nature) = .76; r(future generations) = .75.

Figure 16 Correlation between perceived consequences and acceptability of implementing AR and DACCS in sample of Germany

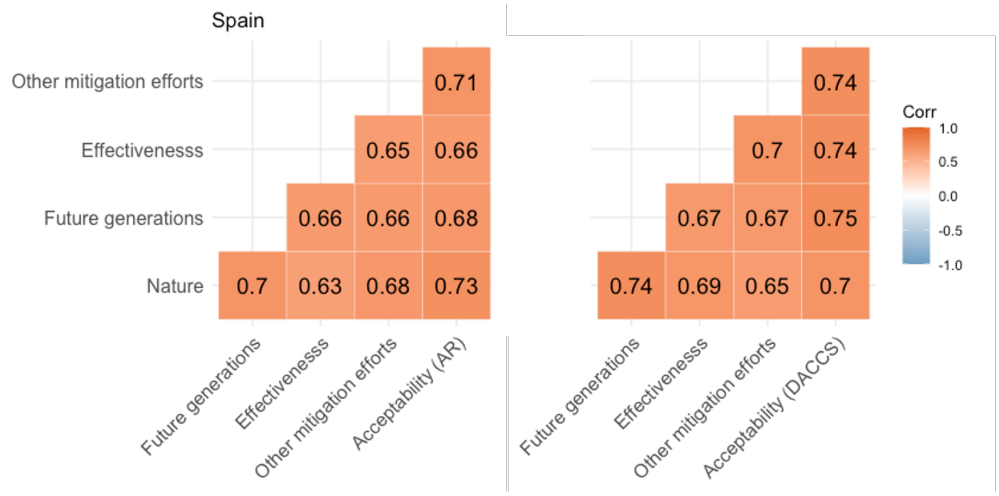


Figure 17 Correlation between perceived consequences and acceptability of implementing AR and DACCS in sample of Spain

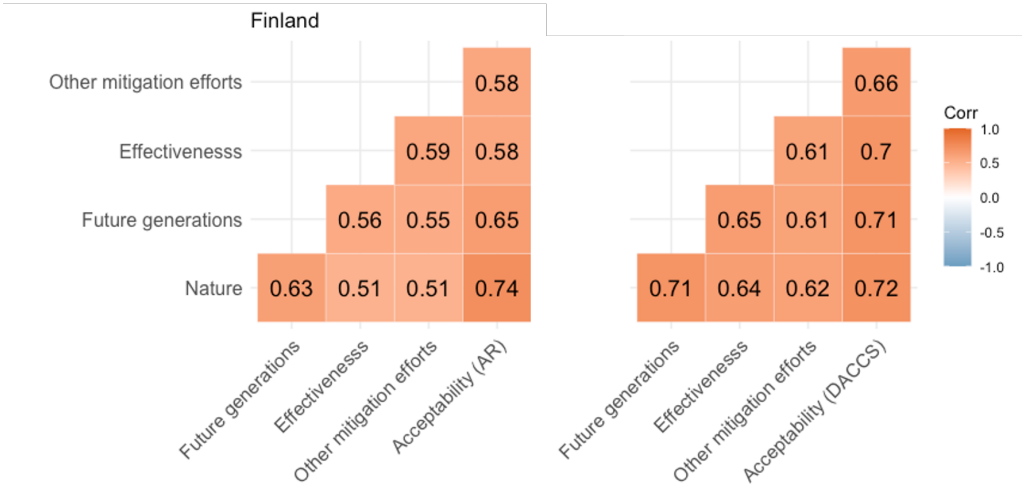


Figure 18 Correlation between perceived consequences and acceptability of implementing AR and DACCS in sample of Finland

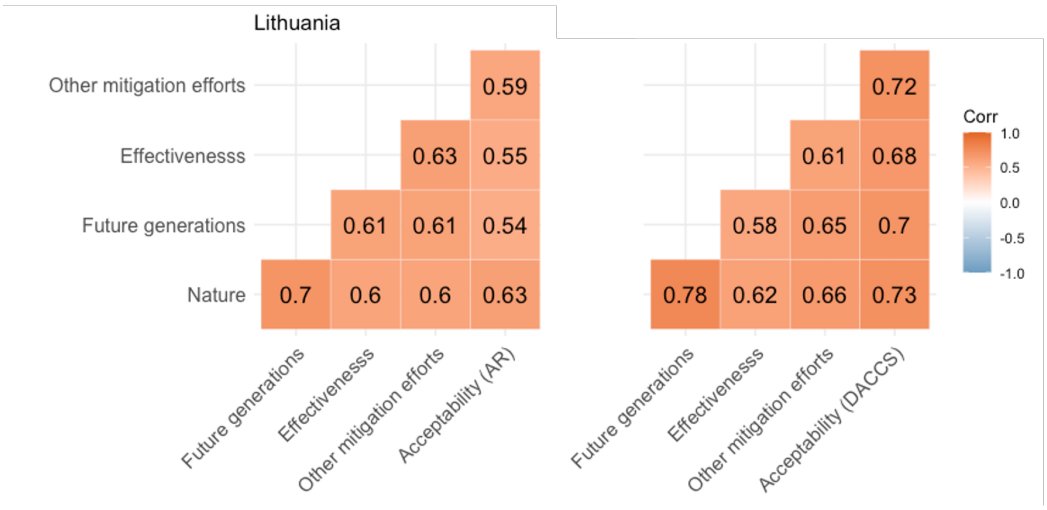


Figure 19 Correlation between perceived consequences and acceptability of implementing AR and DACCS in sample of Lithuania

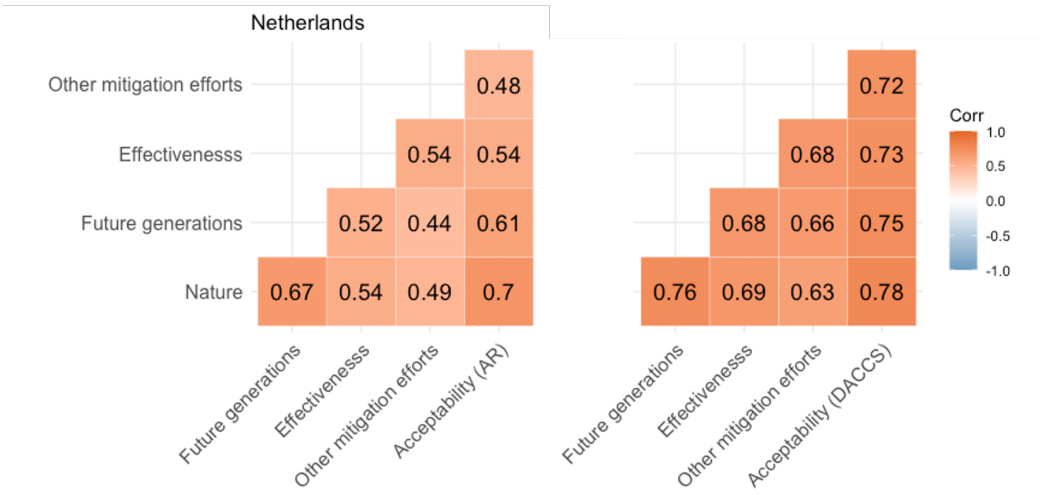


Figure 20 Correlation between perceived consequences and acceptability of implementing AR and DACCS in sample of the Netherlands

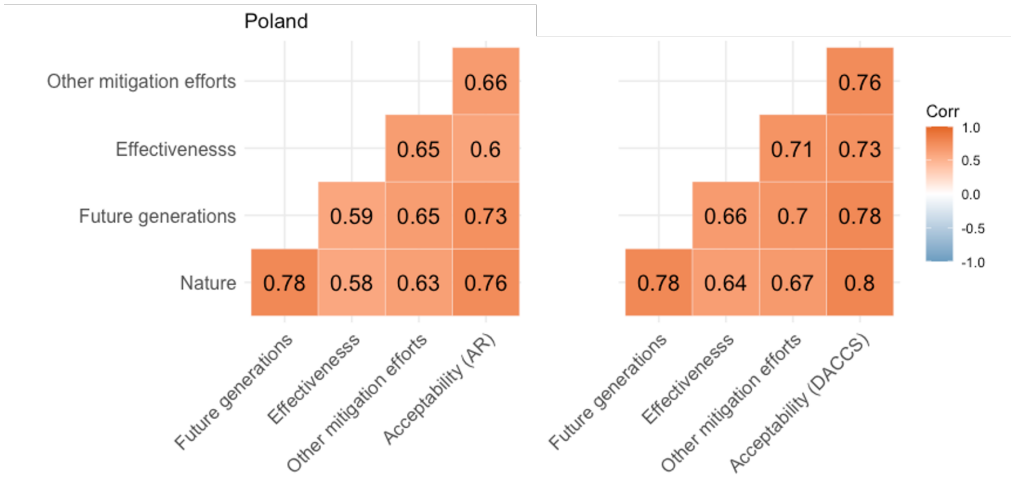


Figure 21 Correlation between perceived consequences and acceptability of implementing AR and DACCS in sample of Poland

2.2 Which countries should implement NETPs?

We wanted to know to what extent the perceptions of a country's responsibility for CO_2 emissions, and their perceived capability of implementing NETPs are related to the extent to which people perceive it is fair and acceptable that the country would implement NETPs. We first studied this via an experimental design. For both AR and DACCS, each participant read one of four different descriptions of a hypothetical country, in which we systematically varied the responsibility and capacity of the country to implement NETPs, respectively. Specifically, the countries differed in their CO_2 emissions, on the one hand, and the knowledge and resources they have available to implement the NETP, on the other hand (see Table 3).

Table 3 Country Descriptions

	High CO_2 emissions	**Low** CO_2 emissions
High capacity to implement NETPs	*This country is one of **the highest CO_2 emitting countries** and has **sufficient knowledge and resources** to implement [AR or DACCS].* (N_{AR} = 1371; N_{DAC} = 1374)	*This country is one of **the lowest CO_2 emitting countries**, yet it has **sufficient knowledge and resources** to implement [AR or DACCS].* (N_{AR} = 1369; N_{DAC} = 1378)
Low capacity to implement NETPs	*This country is one of **the highest CO_2 emitting countries**, yet it has **insufficient knowledge and resources** to implement [AR or DACCS].* (N_{AR} = 1366; N_{DAC} = 1332)	*This country is one of **the lowest CO_2 emitting countries** and has **insufficient knowledge and resources** to implement [AR or DACCS].* (N_{AR} = 1385; N_{DAC} = 1413)

We asked participants to what extent they think the country presented to them is responsible for reducing global CO_2 emissions and to what extent the country is capable of implementing AR or DACCS, respectively. For both technologies, the countries with higher CO_2 emissions were perceived to be significantly more responsible for reducing CO_2 emissions than the countries with lower CO_2 emissions[5]. Similarly, for both technologies, countries with more knowledge and resources are perceived to be significantly more capable of implementing NETPs than countries with less knowledge and resources[6].

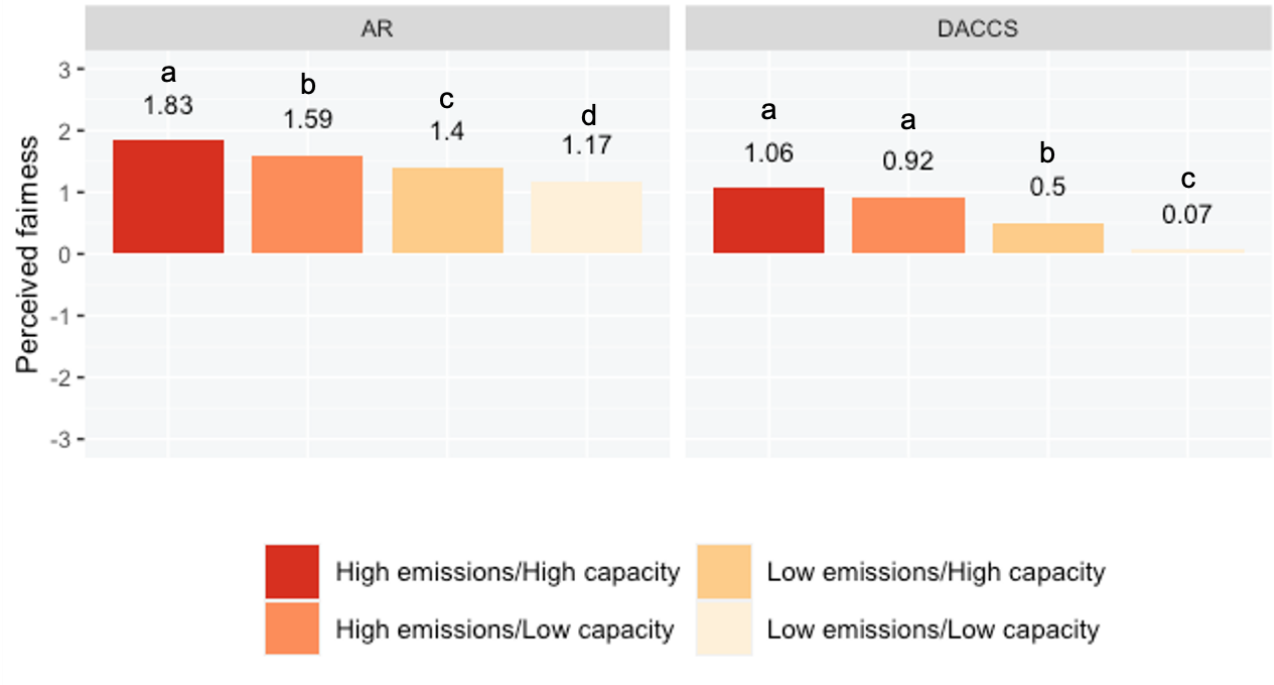
We further asked participants how fair and justifiable they think it is to ask the country described in the scenario to implement AR and DACCS, respectively. Perceived fairness was measured by two items that were rated on a 7-point Likert-type scale ranging from -3 (very unfair/unjustifiable) to 3 (very fair/justifiable). The average scores across the two items were calculated, as the items formed a reliable scale for both NETPs[7]. In

[5] For AR: M(high CO_2) = 1.41, M(low CO_2) = 0.86, t(5437) = 12.5, $p < .001$; for DACCS: M(high CO_2) = 1.08, M(low CO_2) = 0.39, t(5477) = 15.6, $p < .001$.

[6] For AR: t(5457) = 8.9, $p < .001$, M(high resources) = 1.48, M(low resources) = 1.11; for DACCS: t(5447) = 12.6, $p < .001$, M(high resources) = 0.86, M(low resources) = 0.30.

[7] r_{AR} = .86; r_{DAC} = .87.

general, participants saw it as fairer to implement AR than DACCS, as shown in Figure 22. For both NETPs, participants believed it is fairer that the country with higher CO_2 emissions and more knowledge and resources would implement NETPs[8]. Still, CO_2 emissions seem slightly more important, because for both NETPs, participants found it fairer that they are implemented by countries with high emissions but little knowledge and resources than by countries with more knowledge and resources but lower CO_2 emissions. For DACCS, we also found a significant interaction effect of CO_2 emissions and knowledge and resources[9]. Specifically, people believed it is fairer if countries with high CO_2 emissions implement DACCS, independent of their knowledge and resources (p = .10).



Note: different letters (a, b, c, d) indicate significant differences in the mean scores between groups (p < . 05); the same letter indicates no significant difference in the mean scores between groups.

Figure 22 The extent to which CO_2 emissions and capacity of a country affect perceived fairness of AR and DACCS

Similar results were found for the extent that participants find it acceptable that a country presented to them would implement AR or DACCS (see Figure 23). Acceptability was rated by the same items and scales as presented in Section 2.1.2, that is, the extent to which participants believe it is a good/bad idea, (un)necessary and (un)acceptable to implement AR or DACCS in the country described in the scenario. Mean scores of the three items were calculated as the items formed a reliable scale[10]. For both NETPs, participants found it more acceptable to ask the country with higher CO_2 emissions and with more resources to implement NETPs[11]. For both AR and DACCS, the interaction effect between the country's CO_2 emissions and its knowledge and resources was not significant. Similar to previous findings on mitigation measures (e.g., Klebl & Jetten, 2023; Klinsky et al., 2012), for both NETPs, CO_2 emissions seem slightly more important for evaluating which country should act,

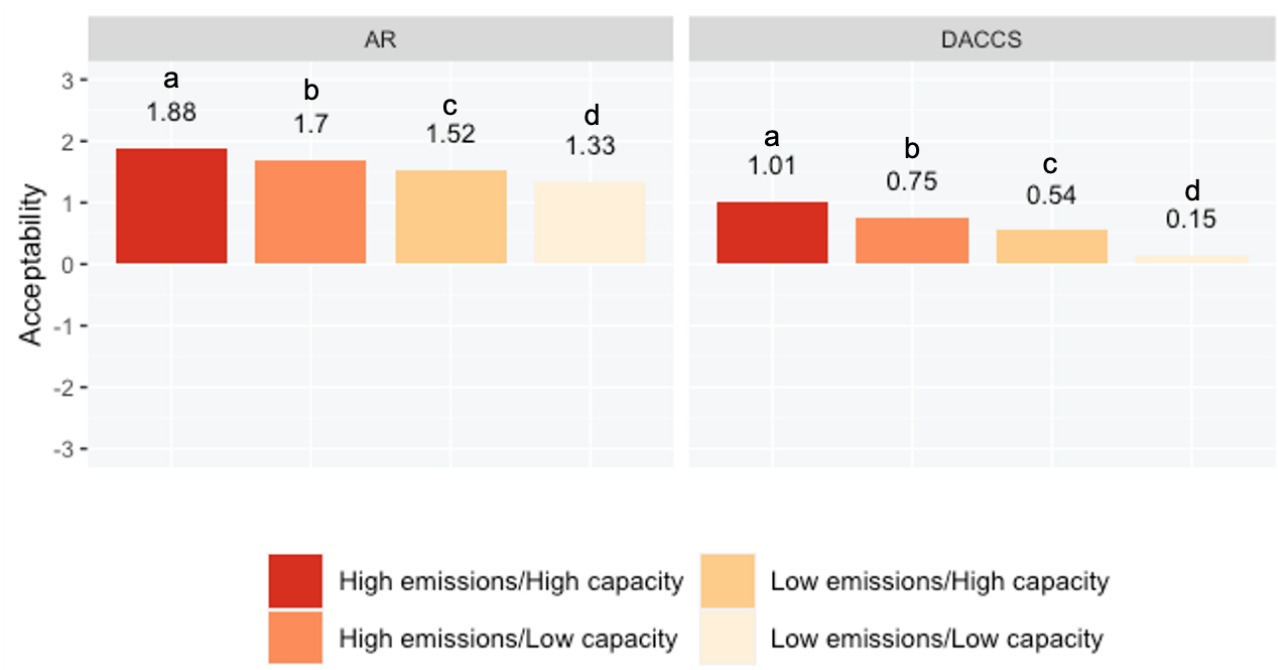
[8] The effect of emissions: $F(1, 5430) = 120.312$, $p < .001$; The effect of resources: $F(1, 5430) = 35.385$, $p < .001$.

[9] The effect of interaction term between emissions and resources: $F(1, 5440) = 11.033$, $p < .001$. The significance of the interaction term means the effect of one variable depends on the levels of the other variable.

[10] Cronbach's $\alpha_{AR} = .94$; Cronbach's $\alpha_{DAC} = .95$.

[11] For AR, the effect of emissions: $F(1, 5402) = 100.391$, $p < .001$; and the effect of resources: $F(1,5402) = 27.213$, $p < .001$; for DACCS, the effect of emissions $F(1, 5423) = 155.527$, $p < .001$; and the effect of resources: $F(1, 5423) = 57.414$, $p < .001$)

since participants found it more acceptable that the NETPs are implemented by countries with high emissions but little knowledge and resources than by countries with more knowledge and resources but lower CO_2 emissions.



Note: different letters (a, b, c, d) indicate significant differences in the mean scores between groups (p < . 05); the same letter indicates no significant difference in the mean scores between groups.

Figure 23 The extent to which CO_2 emissions and capacity of a country affect acceptability of AR and DACCS

2.3 Preferences for NETPs relative to other ways to achieve climate goals

We asked participants to indicate their preferences for different ways to achieve climate goals, to understand how strongly they prefer NETPs implementation relative to other ways to achieve climate goals. Specifically, we asked participants: In your view, what percentage of CO_2 emissions should be reduced by the following methods:

- switching to renewable energy;
- switching to nuclear energy;
- changing behaviour (such as flying less and eating less meat);
- implementing negative emission technologies and practices (NETPs; such as AR or DACCS).

Participants were asked to fill in the preferred percentages for each method in such a way that the total adds up to 100%. Generally, renewable energy was preferred most (37%), followed by behaviour change (24%). As shown in Figure 24, many participants thought that renewables should account for about 25% to 50% of the total CO_2 emission reduction. For behavioural change, most participants preferred the proportion of about 25% CO_2 emission reduction, whereas for NETPs was 18% and for nuclear energy was 20%). There were more

participants indicating that they prefer not to implement NETPs and nuclear energy at all, compared to renewables and behaviour change. These results are similar to previous findings indicating that people think expanding renewables and encouraging behaviour change is the best way to tackle climate change, while expanding nuclear energy and using carbon storage (with fossil fuels) is less preferable (Pidgeon et al., 2008).

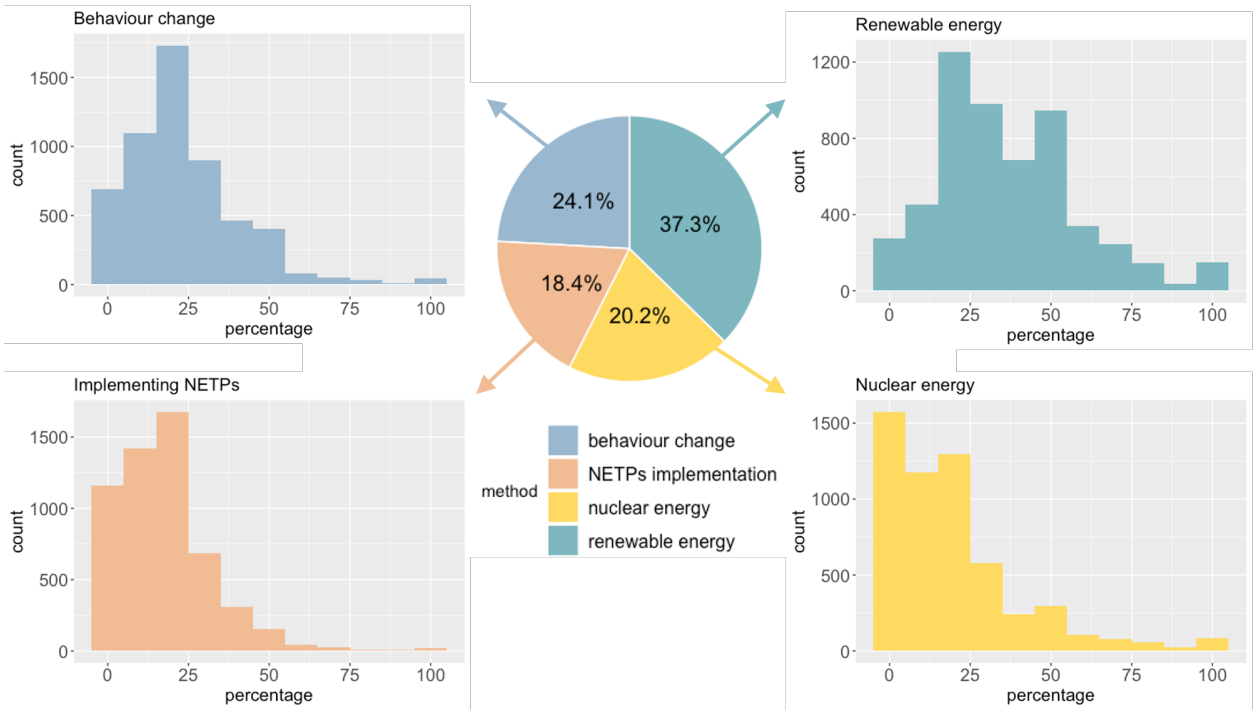


Figure 24 Preferences for ways to reach climate goals

We found some differences in preferences for different ways to reduce net emissions across the six countries, as shown in Figure 25. Spanish respondents indicated a higher preference for renewables (41.3%), while Dutch respondents indicated a relatively higher preference for behavioural change (27.8%); nuclear energy was most preferred in Poland (24.3%) and least in Spain (16.0%); Lithuanian respondents indicated a somewhat higher preference for NETPs than other countries, but these differences were small and, in all countries, the preferred proportion for NETPs was on average between 17% and 20%. Hence, despite a spread of views towards different ways to reduce overall emissions, the relative preference for NETPs was rather similar across the six countries.

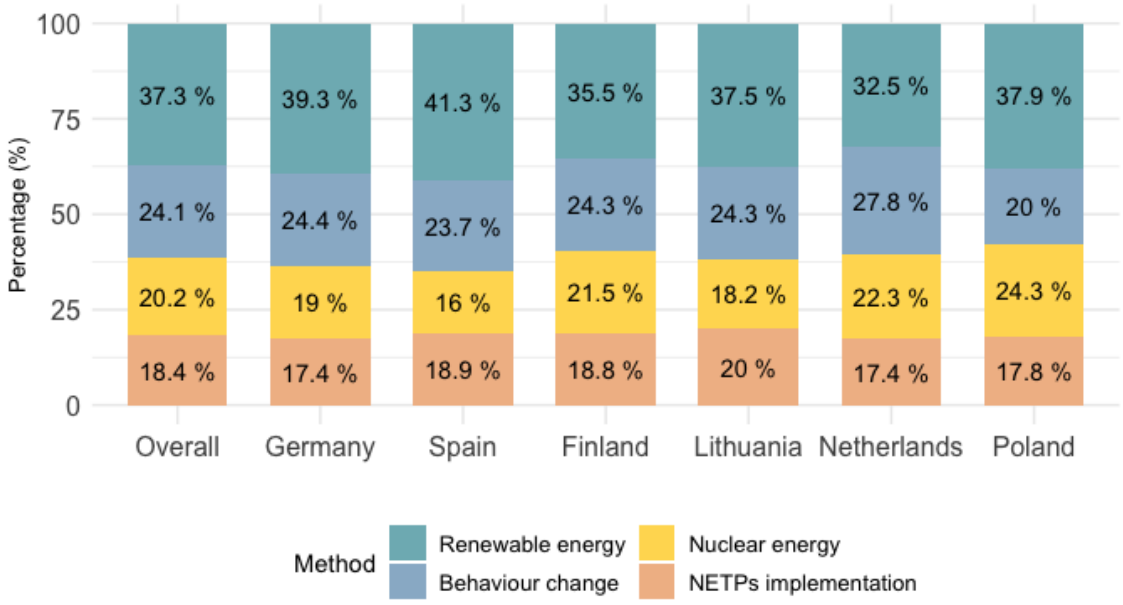


Figure 25 Preferences for ways to reach climate goals, overall and for each country

2.4 Perceived responsibility and perceived capacity of participants' own country to implement NETPs

2.4.1 How much is my country responsible for CO_2 emissions?

Next, we studied the extent to which participants think their own country has currently and historically emitted more CO_2 and the efforts their country has put into limiting emissions compared to most other European countries. These indicators of perceived responsibility for causing climate change were measured by three items that were rated on a 7-point Likert-type scale ranging from -3 (far less than most other European countries) to 3 (far more than most other European countries). Figure 26 shows that people in all countries believed their country has emitted relatively more CO_2 than other European countries in the past and currently (except Finland), and took more action in reducing CO_2 emissions compared to other European countries. Participants in Germany, the Netherlands, and Poland perceived their country as higher emitters, in the past as well as currently. At the same time, people in Germany and the Netherlands believed their country has been putting relatively more effort into reducing CO_2 emissions, compared to most other European countries. Interestingly, participants in Finland in particular indicated that their country has been putting more effort into reducing CO_2 emissions. Compared to the selection criteria we used to select the country for this study (see also Figure 1), respondents in Germany seemed to underestimate their country's contribution to CO_2 emissions. Future studies are needed to examine the discrepancy between absolute emissions and perceived emissions, and how this may affect public acceptability of CDR measures.

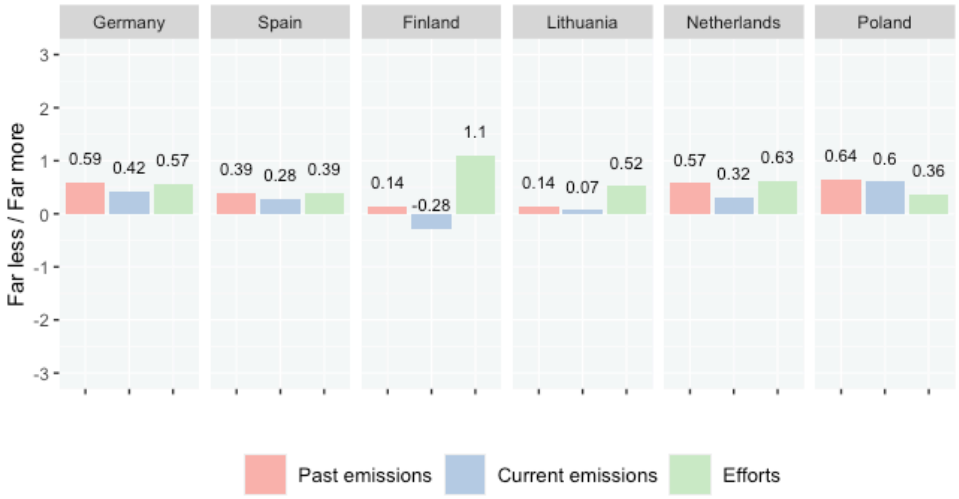


Figure 26 Attributes reflecting perceived responsibility of CO_2 emissions across sample countries

2.4.2 How capable is my country of implementing NETPs?

We next studied the extent participants think their own country is capable of implementing NETPs in general, compared to most other European countries. We asked how they perceive their country's wealth and income, to what extent their country has suitable land or space to implement NETPs, and knowledge to implement NETPs, as indicators of the perceived capacity of their country to implement NETPs. These three items were rated on a 7-point Likert-type scale ranging from -3 (far less than most other European countries) to 3 (far more than most other European countries). Figure 27 shows that people in all countries believe their country has more wealth (except Lithuania), more suitable land (except the Netherlands) and has relatively more knowledge to implement NETPs, compared to other European countries. Germany and the Netherlands were seen as relatively wealthier; Poland, Spain, and Finland were considered as having relatively more suitable land or space for implementing NETPs; the Netherlands and Finland were seen as having relatively more knowledge to implement NETPs.

Figure 27 Attributes reflecting perceived capacity to implement NETPs across sample countries

2.4.3 To what extent do people think it is fair and acceptable that their country would implement NETPs?

Participants evaluated the extent they perceive it to be fair and acceptable that their country would implement AR and DACCS. Perceived fairness was measured by similar items and scales as presented in Section 2.2, that is, the extent to which participants find it is (un)fair and (un)justifiable to ask their country to implement AR and DACCS, respectively. The average across the two items are calculated, as the items formed a reliable scale for both NETPs[12]. Overall, respondents find it fairer that their country would implement AR compared to DACCS[13] (see Figure 28). In Lithuania, the differences of perceived fairness of two NETPs were quite large, compared to other countries, as perceived fairness of AR was relatively much higher. In Finland, perceived fairness of implementing both NETPs was relatively lower than in the other five countries.

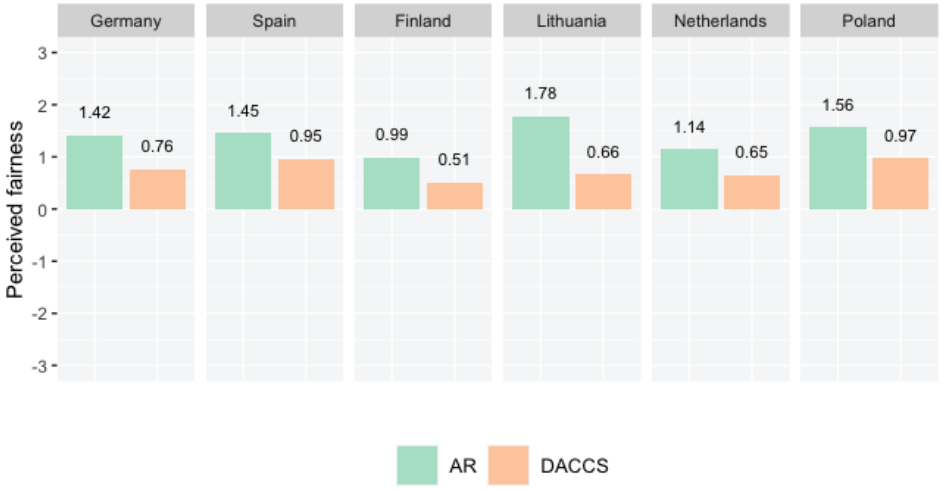


Figure 28 Perceived fairness of implementing AR or DACCS in participants' own country

Acceptability was rated by the same items and scales as presented in Section 2.1.2, that is, the extent to which participants believe it is a good/bad idea, (un)necessary and (un)acceptable to implement AR or DACCS in their country. The average of two items of acceptability were calculated, as items formed a reliable scale for both NETPs[14]. As shown in Figure 29, respondents found it more acceptable that their country would implement AR compared to DACCS[15]. Similar to the results of perceived fairness, the difference between acceptability of AR and DACCS were quite large especially in Lithuania, since the acceptability of implementing AR was higher compared to other countries; acceptability of both NETPs was relatively lower in Finland and the Netherlands.

[12] r_{AR} = .83; r_{DAC}= .85

[13] $t_{DE}(893) = 14.3$, $p < .001$; $t_{ES}(855) = 11.4$, $p < .001$; $t_{FL}(878) = 10.5$, $p < .001$; $t_{LT}(941) = 20.5$, $p < .001$; $t_{NL}(888) = 10.2$, $p < .001$; $t_{PL}(881) = 13.3$, $p < .001$.

[14] Cronbach's α_{AR}= .93; Cronbach's α_{DAC} = .93.

[15] $t_{DE}(892) = 14.0$, $p < .001$; $t_{ES}(852) = 11.3$, $p < .001$; $t_{FL}(879) = 10.8$, $p < .001$; $t_{LT}(934) = 19.3$, $p < .001$; $t_{NL}(889) = 12.4$, $p < .001$; $t_{PL}(876) = 14.0$, $p < .001$.

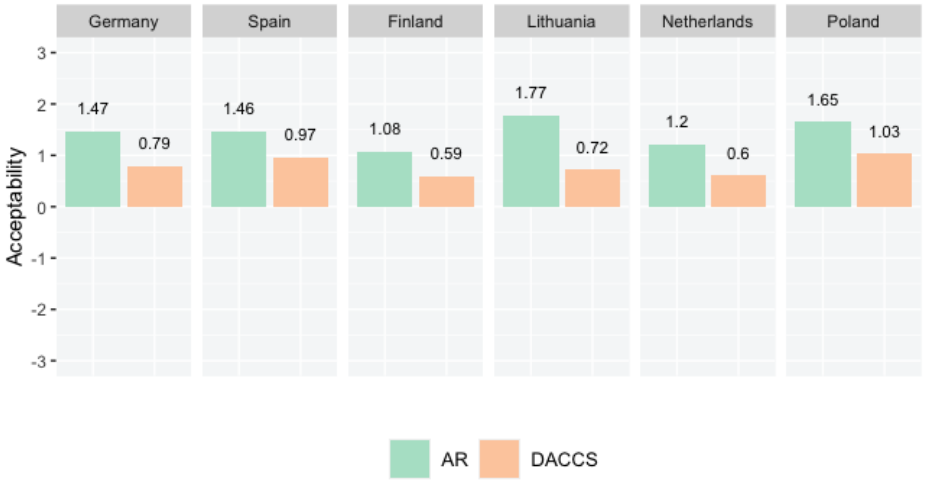


Figure 29 Acceptability of implementing AR or DACCS in participants' own country

2.4.4 Relationships between the perception of responsibility, capacity, fairness and acceptability of implementing NETPs.

Next, we examined to what extent perceived fairness and public acceptability of implementing NETPs in one's own country is related to a country's past and current CO_2 emissions, past efforts into limiting emissions, wealth, suitable land, and knowledge of implementing NETPs. Figure 30 shows strong correlations between perceived fairness and acceptability for both NETPs.

For AR, past emissions, current emissions, and land were moderately strongly correlated with perceived fairness and acceptability, while wealth and knowledge were weakly related with perceived fairness and acceptability. The efforts the country has already put into reducing CO_2 emissions was hardly related to perceived fairness and acceptability of AR.

For DACCS, past emissions, current emissions, wealth, land, and knowledge were moderately strongly correlated with perceived fairness and acceptability, though the correlation between knowledge and perceived fairness and acceptability was slightly weaker. The efforts the country has put in reducing CO_2 emissions was weakly related to perceived fairness and acceptability of DACCS. Interestingly, for DACCS, the perception of available land was still quite strongly related with acceptability, although it was indicated in the description of advantages of DACCS that it requires less land.

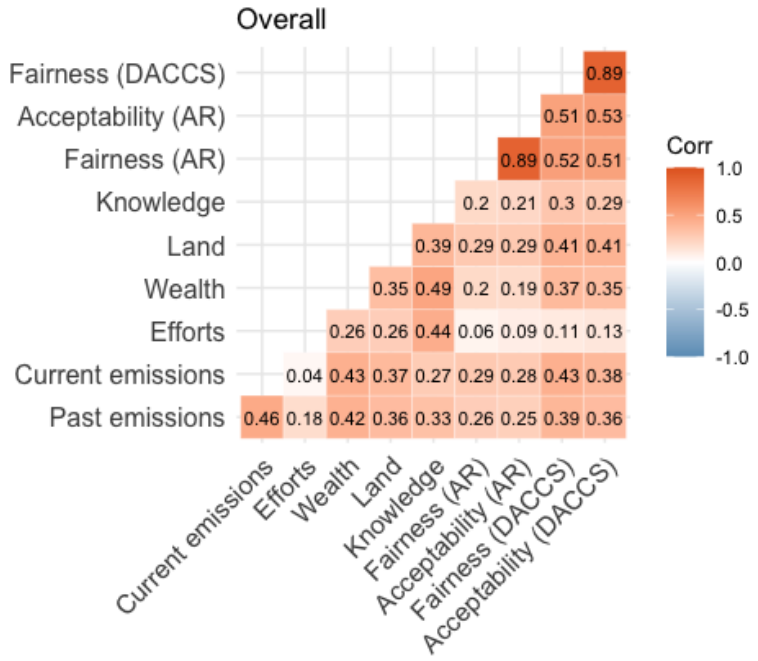


Figure 30 Correlations between attributes and perceived fairness and acceptability of implementing AR and DACCS in participants' own country (overall)[16]

As shown from Figure 31 to Figure 36, strong correlations between perceived fairness and acceptability are found for both NETPs across countries, but subtle differences are found in terms of the strength of the relationship with different attributes.

In Germany (Figure 31), the patterns of the correlations for both NETPs were similar: perceived fairness and acceptability of implementing both NETPs are moderately correlated with past emissions, current emissions, wealth, available land and knowledge; and weakly related to efforts to limit emissions; but for DACCS, past emissions, current emissions, and wealth were much strongly related to perceived fairness and acceptability. In Spain (Figure 32), both perceived fairness and acceptability were moderately strongly correlated with past emissions, current emissions, and available land; and weakly related to the efforts to limit emissions. But for DACCS, perceived fairness and acceptability were also moderately strongly correlated with knowledge and wealth of the country. In Finland and Lithuania (Figure 33 and Figure 34, respectively), the correlations showed slightly different patterns for AR and DACCS. In Finland, perceived fairness and acceptability of both NETPs were moderately strongly related to available land and wealth of the country, and weakly related to knowledge. But for AR, past emissions and current emissions were only moderately weakly related to perceived fairness and acceptability. In Lithuania, different attributes were weakly related to perceived fairness and acceptability of implementing AR, but moderately strongly related to perceived fairness and acceptability of implementing DACCS. In the Netherlands (Figure 35), the patterns of the relationships were similar for both NETPs: perceived fairness and acceptability were moderately strongly related to past emissions, current emissions, wealth, available land and knowledge; though for AR, the correlation between available land, perceived fairness and

[16] "Past emissions" is omitted from the x-axis and "acceptability (DACCS)" is omitted from the y-axis, since the diagonal correlation coefficients will be the correlations of the variables themselves, and thus the number is constantly 1.

acceptability was weaker. In Poland (Figure 36), perceived fairness and acceptability of DACCS were moderately strongly correlated with most attributes, except the efforts to limit emissions; for AR, we found perceived fairness and acceptability were moderately strongly related to available land, and somewhat related to past emissions and current emissions.

The results suggest the strengths of the relationships between the attributes and acceptability of NETPs seemed to differ depending on the country's actual emissions, its unique capacity, and the characteristics of NETPs. For example, perceived past and current emissions remained relatively strongly related to perceived fairness and acceptability of implementing both NETPs in all six countries, with an exception in the acceptability of AR in Lithuania. In countries with larger land areas, like Spain, Finland and Poland, the perception of land capacity was more strongly related to acceptability of NETPs than other attributes; but in Finland, perceived wealth was also strongly related to acceptability of NETPs, while in Spain and Poland, this relationship was relatively weak. The relationships also differed for different NETPs. For DACCS, the attributes reflecting perceived capacity seemed to play a more important role in perceived fairness and acceptability than for AR, which may be due to higher costs and technical requirements for DACCS than for AR. In the Netherlands and Germany, the patterns of the correlations were relatively similar for both NETPs, but in other countries, the correlations for AR and DACCS seemed slightly different. Future research is needed to examine this further.

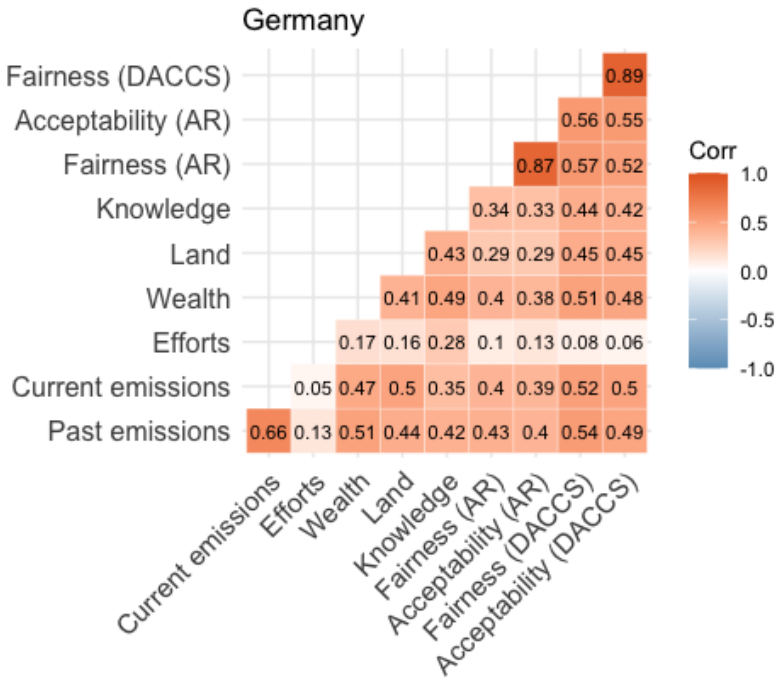


Figure 31 Correlations between attributes and perceived fairness and acceptability of implementing AR and DACCS in participants' own country (Germany)

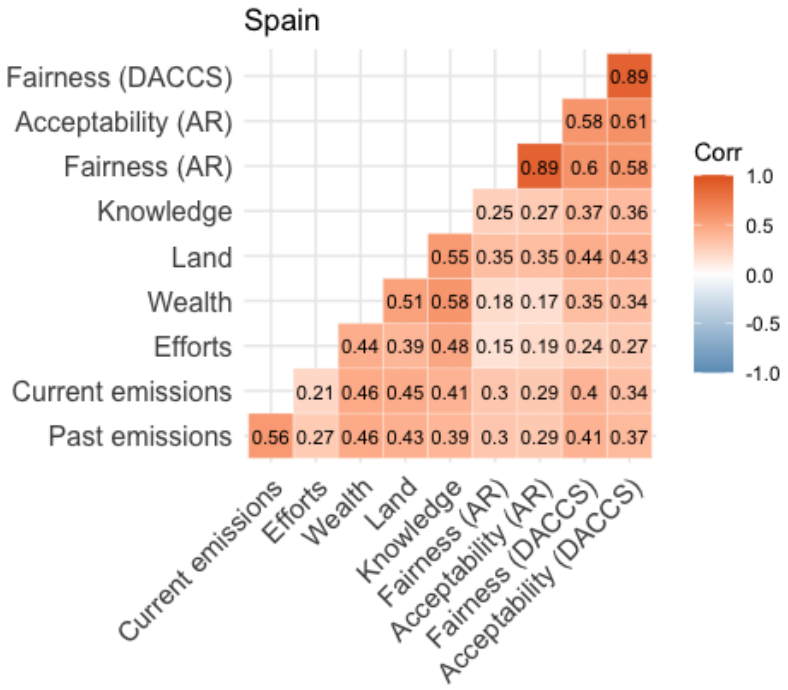


Figure 32 Correlations between attributes and perceived fairness and acceptability of implementing AR and DACCS in participants' own country (Spain)

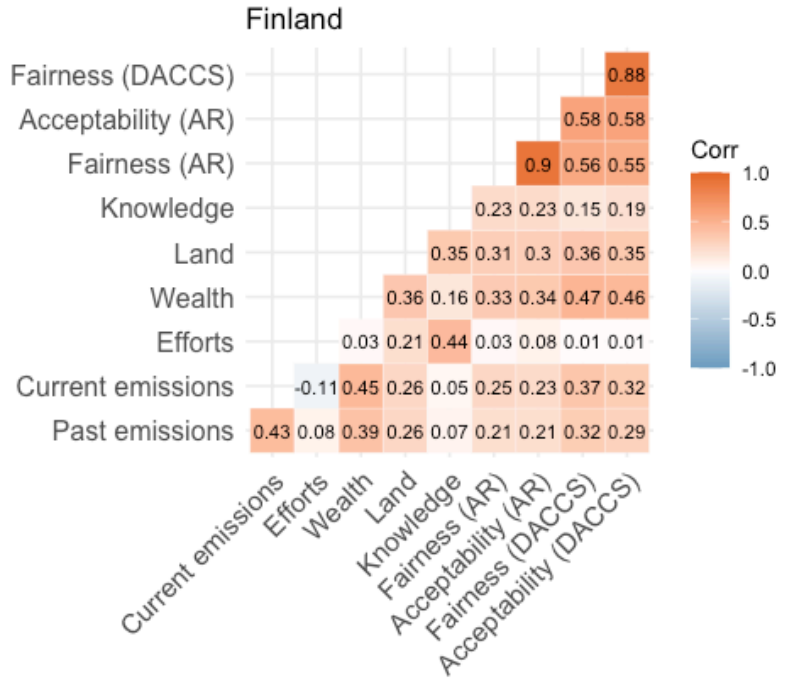


Figure 33 Correlations between attributes and perceived fairness and acceptability of implementing AR and DACCS in participants' own country (Finland)

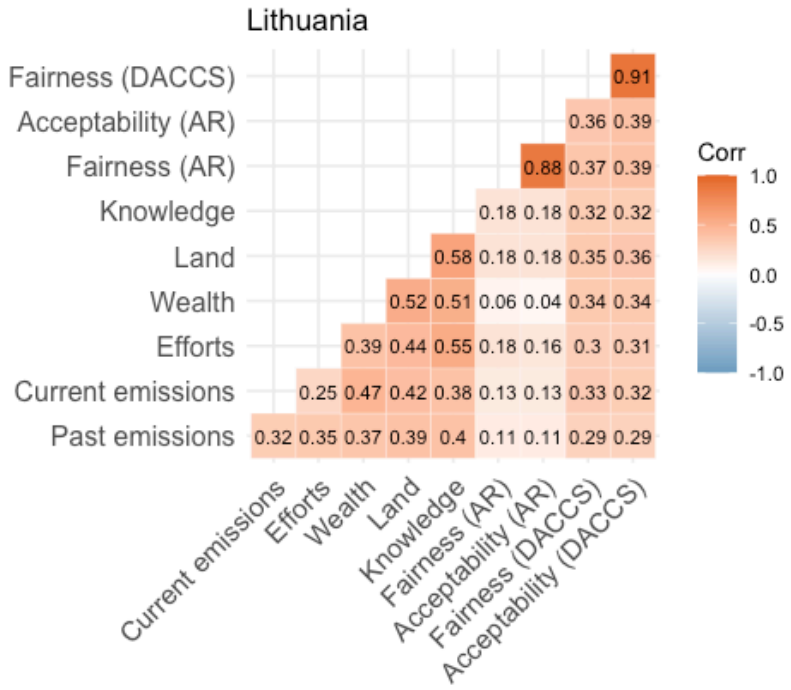


Figure 34 Correlations between attributes and perceived fairness and acceptability of implementing AR and DACCS in participants' own country (Lithuania)

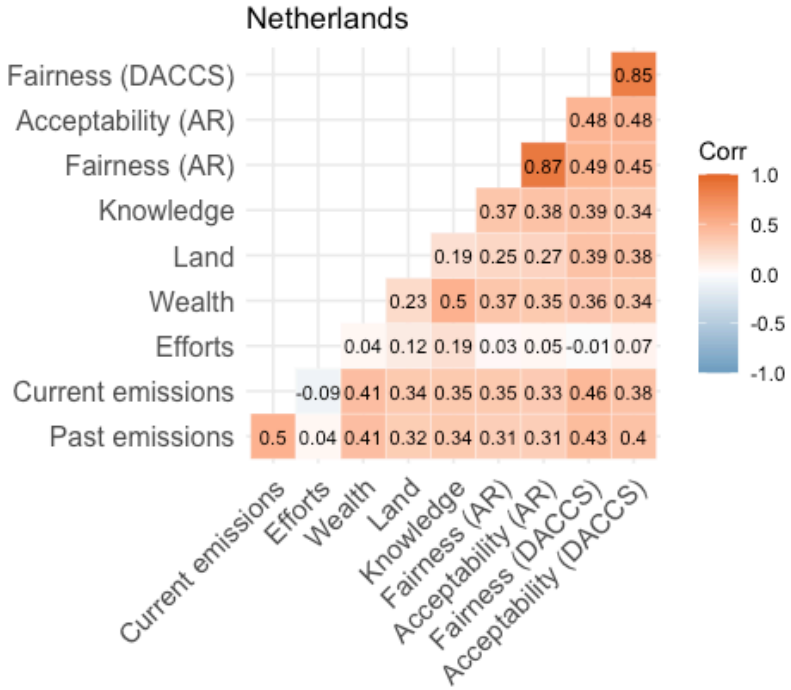


Figure 35 Correlations between attributes and perceived fairness and acceptability of implementing AR and DACCS in participants' own country (the Netherlands)

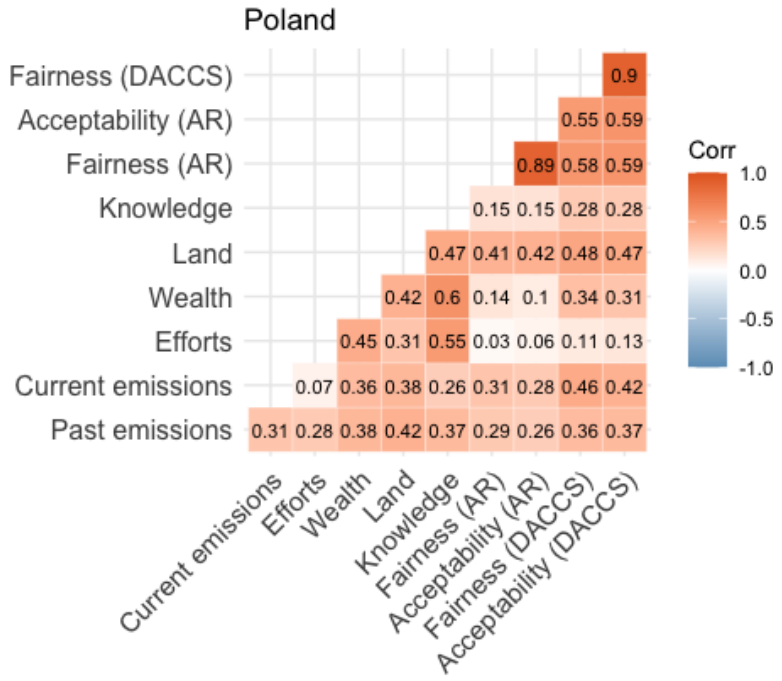


Figure 36 Correlations between attributes and perceived fairness and acceptability of implementing AR and DACCS in participants' own country (Poland)

2.5 Preferences for public participation in decision-making about the development of NETPs

Participants evaluated different ways of public participation in the decision-making process about NETPs. Specifically, we asked participants how desirable (from -3 not at all desirable to 3 very desirable) and necessary (from -3 not at all necessary to 3 very necessary) it is to involve the public in decision-making about the development of NETPs in the following four ways:

- inform the public about the development of NETPs ("inform")
- let the public express their opinion about the development of NETPs ("opinion")
- let the public decide together with governments and experts about the development of NETPs ("co-decide")
- let the public themselves take decisions about the development of NETPs ("decision").

Figure 37 shows the overall preference of different types of public participation. In general, most respondents find involving the public is desirable and necessary. Specifically, a large proportion of respondents (around 80%) indicates that informing the public and letting the public express their opinion is desirable and necessary, while co-deciding with governments and experts is desirable and necessary for approximately 70% of the respondents (20% neutral and 10% found it undesirable and unnecessary). Most respondents find taking decisions by the public is preferable (around 55%), but around 25% evaluate this as neutral and 20% find it undesirable and unnecessary.

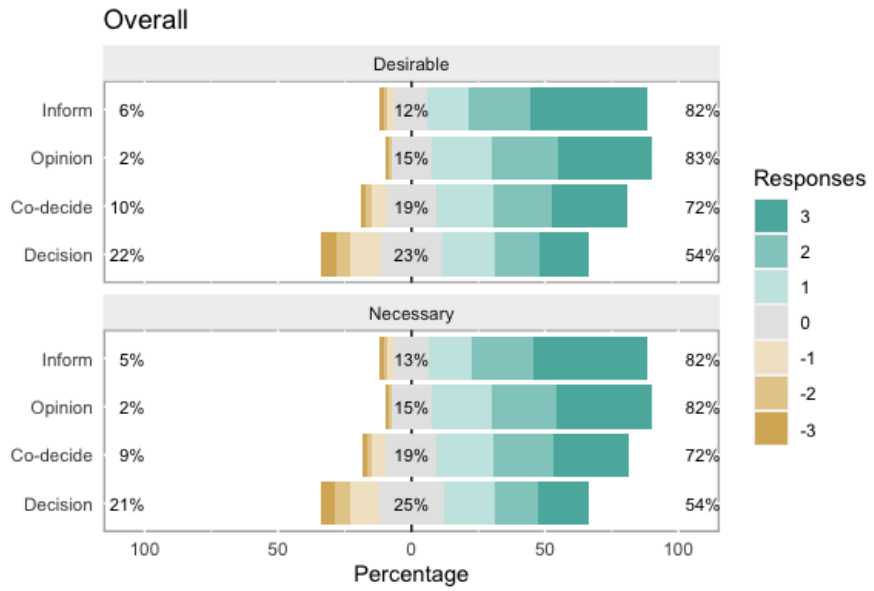


Figure 37 Overall preference of public participation in decisions about the development of NETPs

When we looked into country differences (Figure 38 to Figure 41), Germany showed similar patterns with the overall sample. In Spain and Lithuania, respondents found making decisions by the public slightly more desirable and necessary compared to the overall sample (around 60%), while respondents in Finland and the Netherlands found it less desirable and necessary than the overall sample (around 40%). In Poland, informing, giving opinions, and co-deciding with experts were found to be highly desirable and necessary by the majority of respondents (nearly 90%).

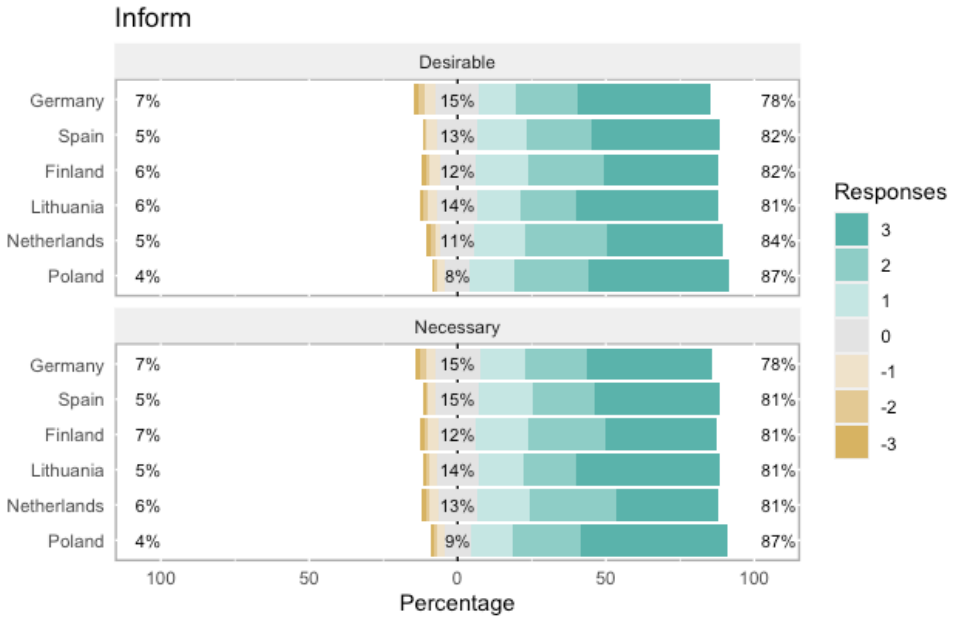


Figure 38 Preference for informing the public about the development of NETPs

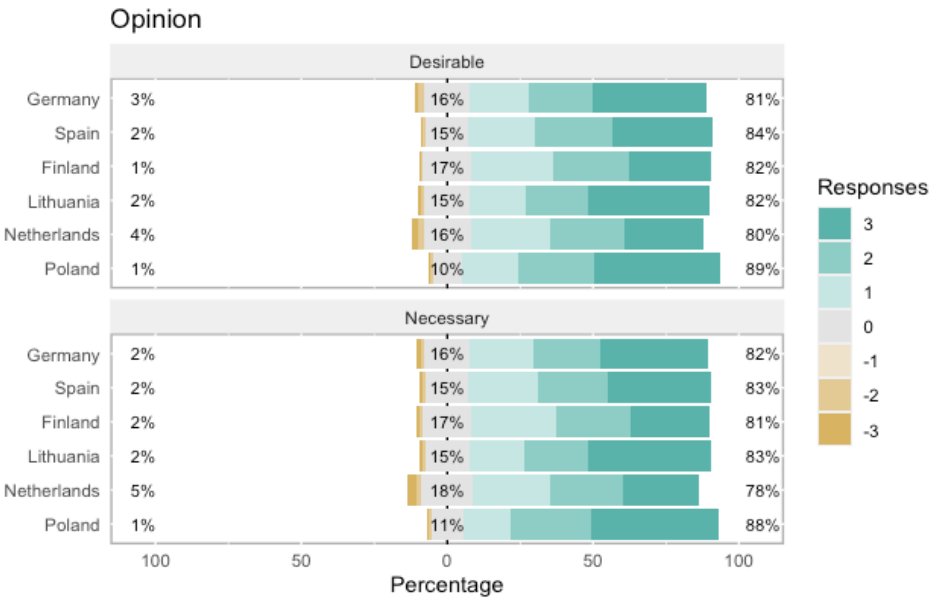


Figure 39 Preference for expressing one's opinion about the development of NETPs

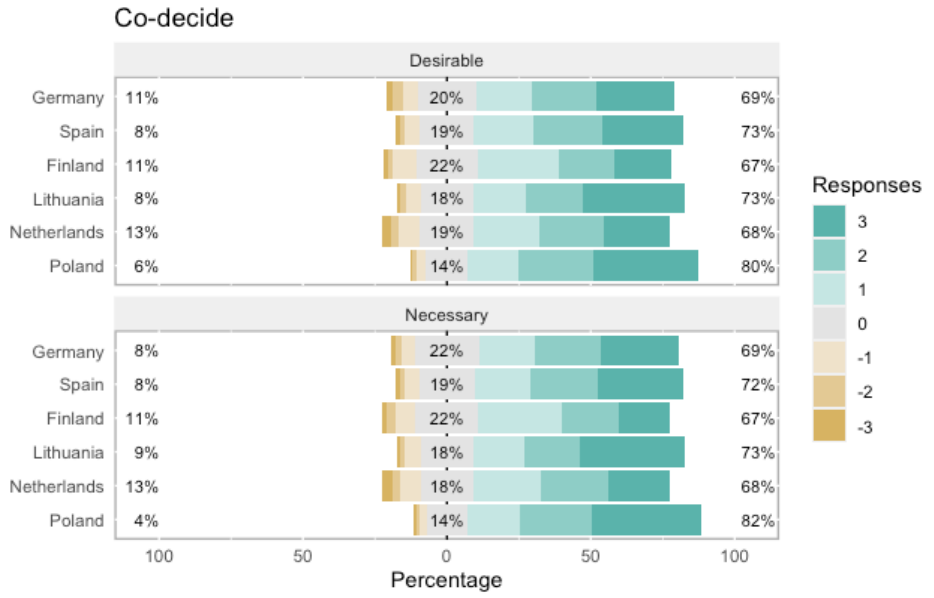


Figure 40 Preference for deciding together with government and experts about the development of NETPs

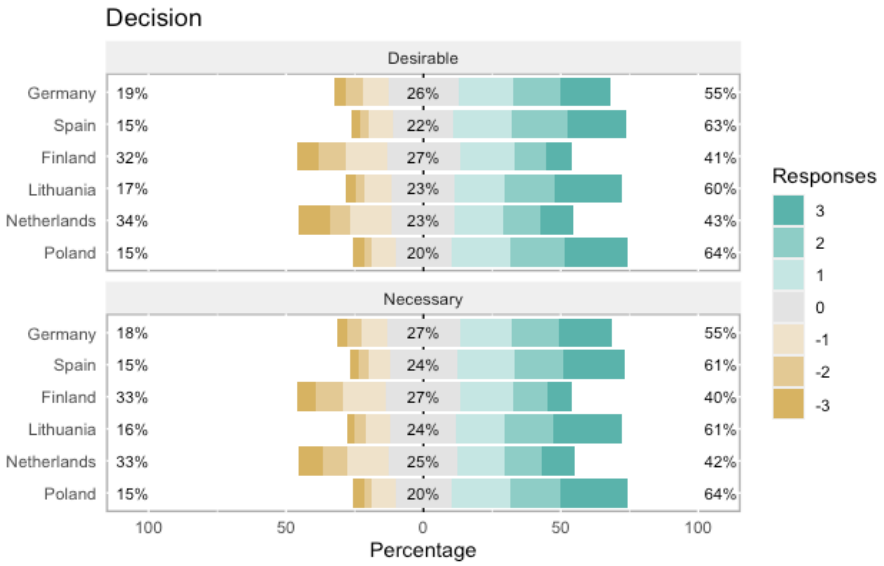


Figure 41 Preference for making decision by the public about the development of NETPs

We then calculated the mean scores of perceived desirability and necessity for each kind of participation, as the items formed a reliable scale[17]. Figure 42 shows the average preference of the forms of public participation. In general, respondents prefer informing and expressing their opinions about the development of NETPs, followed by co-deciding with government and experts and deciding by the public[18]. Previous research also showed that people do not necessarily prefer to have full influence over the decision making, but prefer to be informed and to be able to express their opinions (Liu et al., 2021). Interestingly, respondents in Finland and the Netherlands show less interest in the public deciding on their own compared to other countries, while respondents in Poland show higher preference in informing, giving opinions and co-deciding. A possible explanation is that respondents in Finland and the Netherlands generally had higher trust in the public system of their countries (Schmidthuber et al., 2021), and therefore making decisions by the public was considered as less needed.

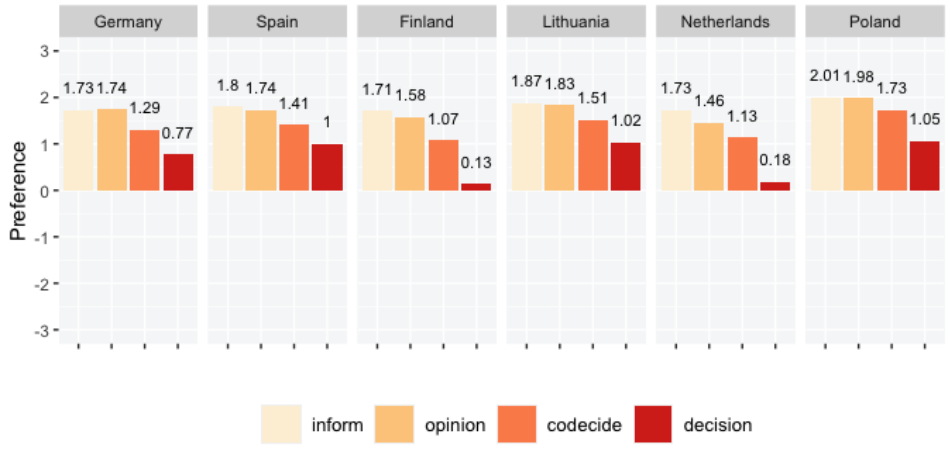


Figure 42 Preference of public participation in decisions about the development of NETPs per country

[17] *r*(inform) = .85; *r*(opinion) = .80; *r*(co-decide) = .85; *r*(decide) = .87.

[18] $F(3, 15939) = 1423$, $p < .001$; inform vs. opinion: $t(5350) = 5.93$, $p < .001$; inform vs. codecide: $t(5357) = 24.6$, $p < .001$; inform vs. decision: $t(5360) = 44.4$, $p < .001$; opinion vs. codecide: $t(5359) = 25.0$, $p < .001$; opinion vs. decision: $t(5361) = 49.9$, $p < .001$; codecide vs. decision: $t(5373) = 35.5$, $p < .001$.

3 Discussion

In this study, we investigated public acceptability of AR and DACCS and the factors that determine in which countries people think it is most adequate to implement NETPs. Specifically, we studied to what extent perceived fairness and acceptability of implementing AR and DACCS are based on people's perceptions of consequences of implementing NETPs, perceived countries' responsibility for CO_2 emissions, and perceived countries' capacity to implement NETPs. In addition, we explored public perceptions of the role of NETPs in achieving net-zero targets, along other mitigation measures, and public preferences for how to involve citizens in decision-making on NETPs.

The results from a large-scale public survey across six European countries (i.e., Germany, Spain, Finland, Lithuania, the Netherlands, and Poland) revealed that across countries, AR was more acceptable than DACCS, and the consequences of AR were seen more positively than the consequences of DACCS. These findings are in line with previous research that suggested that people generally prefer nature-based solutions over technology-based solutions (Jobin & Siegrist, 2020; Merk et al., 2023; Wenger et al., 2021; Wolske et al., 2019). Interestingly, AR was seen more positively even when we provided participants with information about some possible disadvantages of AR, such as extensive land use and possible CO_2 leakage when trees were cut or rot, and some possible advantages of DACCS, such as less land use and that CO_2 can be stored for a long time. This is in line with previous findings that also indicate that people find AR more acceptable than DACCS although the advantage of DACCS (I.e., long-term carbon storage) and the disadvantage of AR (i.e., possible CO_2 leakage) were presented (Jobin & Siegrist, 2020). Overall, AR was seen rather positively, whereas DACCS was seen more neutrally. Interestingly, for neither we saw a clear division between large groups of supporters and opponents, suggesting that at least at the moment neither AR nor DACCS is a very polarised topic in society. Yet, continuous research is needed to see whether and how public opinion about NETPs changes over time, for example, when people become more familiar with NETPs, including possibly experiencing the actual consequences of implementing NETPs.

Even though participants learned that DACCS could remove CO_2 quickly and store it for a long time, AR was nevertheless evaluated more positively not only on the consequences for nature and future generations, but also on the effectiveness of limiting global warming and effects on other mitigation efforts. As AR was seen as more favourable than DACCS, it is possible that people prefer AR merely for the fact that it is a nature-based solution. Indeed, the perceived consequences for nature and the environment were associated particularly strongly with acceptability of AR, while for DACCS all consequences (for nature, future generations, effectiveness, effects on other mitigation measures) were relatively strongly associated with acceptability. In other words, while being a nature-based solution might already earn public support for AR, for DACCS people may be more critical and take different consequences into account in their acceptability judgements.

For both NETPs, perceived fairness correlated very strongly with acceptability. Perceived fairness, in turn, was associated with a country's responsibility for CO_2 emissions and the capacity to implement NETPs (i.e., available land, wealth, and knowledge). People considered it fair that larger emitters and countries with more resources would implement NETPs. While both factors seem important for perceived fairness, we still observed that CO_2 emissions of a country played a slightly stronger role in perceived fairness of implementing NETPs in that country. In other words, people particularly considered it fair that countries with highest CO_2 emissions implement NETPs, even if they have somewhat less capacity. Extending previous research findings (e.g., Klebl & Jetten, 2023), public acceptability of implementing net-zero system changes not only depends on a country's wealth, but also, and primarily, on a country's carbon footprint.

Also when considering their own country, people evaluated the implementation of AR as more acceptable and fairer than DACCS. In Lithuania, the implementation of AR was seen as most acceptable and fair compared to other countries. In all countries, except Finland, participants thought their own country has emitted more CO_2 than other European countries. As regards the capacity to implement NETPs, people in Finland and the Netherlands evaluated their country relatively highly on knowledge about how to implement NETPs; respondents in the Netherlands thought they had little land to implement NETPs; and respondents in Lithuania thought their country was relatively less wealthy. Participants' own country's past emissions, current emissions, wealth, available land and knowledge were somewhat related to their perceived fairness and acceptability of implementing AR and DACCS. Adding to previous research showing that the perception of a country's wealth is related to the acceptability of structural climate policies (e.g., Klebl & Jetten, 2023, Klinsky et al., 2012), we further showed that public acceptability may also depend on other attributes of capacity, such as land and knowledge to implement the technology. Interestingly, while in all countries people thought their country has put more effort than most other European countries in reducing CO_2 emissions, this was hardly associated with acceptability and perceived fairness of implementing NETPs in their country. So, even if people think their country might have done a lot already to mitigate climate change, this does not necessarily mean they think the country should not implement NETPs. This result suggests that previous efforts to cut CO_2 emissions seem not a barrier to acceptability of implementing NETPs.

When it comes to different ways to reduce total CO_2 emissions, participants in all countries prioritised expansion of renewables, followed by behaviour change (including rather stringent measures such as flying less and eating less meat). In comparison, people preferred a smaller proportion of total CO_2 to be reduced by using nuclear energy and NETPs, around 20 % for each. Still, people allocated at least some share to all different mitigation options, suggesting that on average, people consider multiple solutions needed to mitigate climate change. Importantly, people preferred more CO_2 emissions to be reduced via other mitigation options than CDR, meaning they do not expect implementation of NETPs to be prioritised and to replace other mitigation measures.

As regards citizen engagement in decision-making on NETPs, people in all countries wanted citizens to be informed, have a voice, and to be able to co-decide with governments and experts about NETPs. Contrary to the traditional "participation ladder" proposing that people prefer high influence in the decision making process (Arnstein, 1969), people actually generally did not think citizens should make decisions themselves about NETPs. Recent research also showed that higher influence over the decision does not necessarily lead to higher acceptability of energy projects; people want to be engaged and taken seriously, but not necessarily to co-decide with experts or decide by the public. Acceptability may also depend on people's trust in stakeholders and what kind of decision they can take (Liu et al., 2020; Liu et al., 2021). Yet, in Lithuania, Spain and especially Poland, people were more in favour of the public taking decisions themselves than in Finland and the Netherlands. The differences between countries could be related to the public's perception of how much influence they have in policy-making in their country at the moment, perceived transparency and openness of the government, and trust in the public system (Schmidthuber et al., 2021). Future research is needed to investigate further.

4 Conclusions

- In general, people found AR (a nature-based solution) more positive and acceptable than DACCS (a technology-based solution). The perception of consequences on nature were strongly related to acceptability of both NETPs but we see other influences on acceptability of DACCS, such as the effectiveness of DACCS in limiting global warming and the effects on other mitigation efforts. While technology-based NETPs were generally perceived as tampering with nature, the technology itself needs to assure the public its effectiveness and how it may support mitigation measures to secure higher acceptability.
- Legitimacy of implementing NETPs in a country depends on the perception of a country's CO_2 emissions and capacity (i.e., resources and knowledge), and a country's carbon footprints may be more crucial for evaluating the fairness and acceptability of implementing both NETPs than perceived capacity. Implementing NETPs by a country with higher emissions and lower capacity was perceived to be fairer than by a country with higher capacity and lower emissions. Therefore, addressing responsibility for emissions could be important in allocating NETPs across countries, as implementing NETPs was perceived to be fairer and more acceptable the higher the carbon footprint of a country.
- Multidimensional considerations of allocating CDR targets and implementing NETPs is important to ensure a fair and acceptable pathway. Besides the general focus on which country should do more based on historical emissions, current emissions, and wealth of a country, other attributes of capacity, such as available land and knowledge, could also be addressed in future discussion. Importantly, based on the diverse but unique capacity of implementing NETPs in each country, it would be valuable to initiate cooperations between countries, especially collaboration between countries with more financial resources but limited spatial opportunities and countries with less financial resources but more available land.
- In terms of achieving net-zero emissions, people took multiple options into account, especially switching to renewable energy and changing behaviour were prioritised and deemed more important than nuclear energy and CDR measures. People also recognised the importance of implementing NETPs in the net-zero pathway, but CDR should not replace mitigation measures.
- Regarding public participation in the decision-making process of NETPs, people preferred to be informed and have a say during the development of NETPs, but are generally not in favour of taking decisions fully by themselves. Given different political contexts in European countries, the design of public participation should also consider general trust in public systems and transparency of the governments in each country.

For preparing this report, the following deliverable/s have been taken into consideration:

D#	Deliverable title	Lead Beneficiary	Type	Dissemination level	Due date (in MM)
4.3	Identify Member state targets for CDR	ICL	R	Public	17
5.1	NETP analogues and Social License to Operate	UCAM	R	Public	18

5.3	Stakeholder views on NETP governance	UCAM	R	Public	18
7.2	Extended MONET-EU	ICL	R	Public	17
8.1	Stocktaking of scenarios with negative emission technologies and practices - Documentation of the vision making process and initial NEGEM vision	VTT	R	Public	8

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NEGEM

Appendix A - Composition of representative sample of each country

Table 4 Composition of representative sample of Germany

	Samples (N=931)	Quotas
Age		
18-24	7.3%	8.8%
25-34	13.2%	15.1%
35-54	31.3%	31.5%
55+	48.0%	44.6%
Gender		
man	47.6%	48.9%
woman	52.1%	51.1%
Education		
Low	22.7%	15.7%
Medium	56.4%	58.8%
High	20.5%	25.5%
Region		
Nielsen I	16.8%	16.2%
Nielsen II	21.9%	21.5%
Nielsen IIIa	14.3%	13.7%
Nielsen IIIb	13.4%	13.3%
Nielsen IV	15.0%	15.8%
Nielsen V(a&b)	4.0%	4.4%
Nielsen VI	7.5%	7.7%
Nielsen VII	7.0%	7.5%

Table 5 Composition of representative sample of Spain

	Samples (N=878)	Quotas
Age		
18-24	7.4%	8.6%
25-34	12.1%	13.5%
35-54	36.4%	37.6%

55+	43.7%	40.4%
Gender		
man	48.2%	48.5%
woman	51.3%	51.5%
Education		
Low	44.6%	44.3%
Medium	22.9%	22.3%
High	31.9%	33.4%
Region		
Noroeste	9.8%	9.4%
Noreste	9.5%	9.5%
Comunidad de Madrid	15.1%	14.1%
Centro	11.6%	11.8%
Este	29.6%	29.2%
Sur	21.2%	21.1%
Canarias	2.6%	4.8%

Table 6 Composition of representative sample of Finland

	Samples (N=892)	Quotas
Age		
18-24	7.6%	9.5%
25-34	16.5%	15.8%
35-54	34.4%	30.6%
55+	41.4%	44.1%
Gender		
man	45.9%	49.0%
woman	53.8%	51.0%
Education*		
Low	11.0%	20.4%
Medium	48.4%	45.0%
High	38.6%	34.6%
Region		
Pohjois-Suomi / Itä-Suomi	20.6%	22.9%

Länsi-Suomi	25.4%	24.9%
Etelä-Suomi, Åland	53.6%	52.2%

* Not request representative from Ipsos

Table 7 Composition of representative sample of Lithuania

	Samples (N=994)	Quotas
Age		
18-24	9.3%	8.8%
25-34	15.2%	16.4%
35-54	32.4%	32.5%
55+	42.4%	42.3%
Gender		
man	49.7%	46.1%
woman	50.2%	53.9%
Education*		
Low	2.8%	10.0%
Medium	40.8%	52.2%
High	55.2%	37.8%
Region*		
Alytaus apskritis	6.1%	4.9%
Kauno apskritis	20.4%	20.3%
Klaipėdos apskritis	13.1%	11.4%
Marijampolės apskritis	5.0%	4.8%
Panevėžio apskritis	7.2%	7.6%
Šiaulių apskritis	9.8%	9.4%
Tauragės apskritis	4.2%	3.2%
Telšių apskritis	6.6%	4.6%
Utenos apskritis	5.7%	4.6%
Vilnius apskritis	21.7%	29.3%

* Not request representative from Ipsos

Table 8 Composition of representative sample of the Netherlands

	Samples (N=916)	Quotas
Age		
18-24	8.7%	10.7%
25-34	14.3%	16.0%
35-54	32.0%	31.9%
55+	44.8%	41.4%
Gender		
man	48.3%	49.3%
woman	51.6%	50.7%
Education		
Low	27.7%	26.3%
Medium	36.4%	38.0%
High	35.5%	35.7%
Region		
Noord-Nederland	11.5%	10.0%
Oost-Nederland	21.6%	20.9%
West-Nederland	48.4%	47.6%
Zuid-Nederland	18.6%	21.5%

Table 9 Composition of representative sample of Poland

	Samples (N=901)	Quotas
Age		
18-24	9.4%	8.6%
25-34	15.9%	16.8%
35-54	37.6%	35.7%
55+	36.3%	38.9%
Gender		
man	49.4%	47.7%
woman	50.2%	52.3%
Education		
Low	6.3%	9.7%
Medium	63.7%	63.4%
High	28.1%	26.9%

Region		
Makroregion Centralny	9.9%	9.7%
Makroregion Poludniowy	22.1%	20.7%
Makroregion Wschodni	13.4%	14.0%
Makroregion Pólnocno-Zachodni	15.8%	16.2%
Makroregion Poludniowo-Zachodni	9.4%	10.2%
Makroregion Pólnocny	14.0%	15.1%
Makroregion województwo mazowieckie	15.1%	14.1%

Appendix B - Survey questions

Part 1 - introduction of NETPs

Introduction of Negative Emission Technology and Practices

Climate change has severe consequences around the world, such as more heat waves, wildfires, floods and rising sea levels. To limit climate change, we need to reduce the concentration of greenhouse gas emissions in the atmosphere, such as carbon dioxide (CO_2).

CO_2 mostly comes from burning fossil fuels, such as coal, oil and gas. We can reduce CO_2 emissions by using less energy and switching to renewable energy sources, such as solar and wind energy. However, some greenhouse gas emissions will continue to be emitted, and CO_2 concentrations in the atmosphere need to be reduced over time. CO_2 in the air could be removed and stored underground or in the ocean by using negative emission technologies and practices (NETPs).

There are different kinds of NETPs. In the next section, we will provide a brief description of one type of NETPs, and ask what you think of it. After that, we will explain another type of NETPs and ask your opinion about it.

Part 2 - introduction of AR/DACCS

Afforestation and reforestation means planting more trees to absorb CO_2 from the air and store it in growing trees and soil. Afforestation means planting additional trees in an area where there was no forest before. Reforestation means replanting trees in an area where the forest had been killed by pests, cut down or burned in forest fires earlier.
Below gives an overview of pros and cons of afforestation and reforestation.

Direct air capture with carbon storage (DACCS) filters CO_2 out of the air so it can be stored. The air without CO_2 is released back into the atmosphere, just like a big air purifier. The captured CO_2 is then stored as a liquid in underground storages.

Below gives an overview of pros and cons of direct air capture with carbon storage.

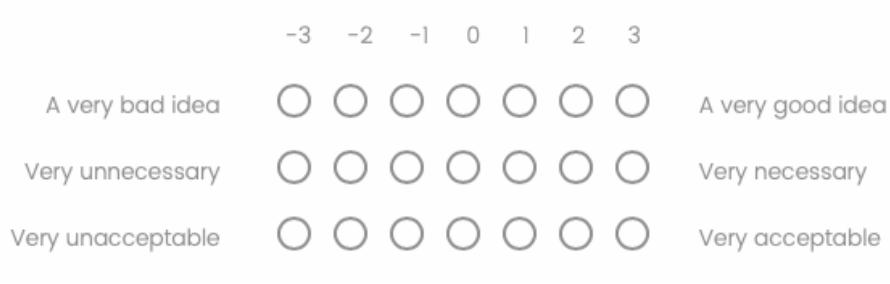
Part 3 - perceived consequences and acceptability of AR/DACCS

We are interested in your opinion about the consequences of [afforestation and reforestation/DACCS]. Please read each statement below carefully and select the option that fits your opinion best. You can evaluate each consequence from very negative (-3) to very positive (3).

1. I think the implementation of [afforestation and reforestation/DACCS] would…

	-3	-2	-1	0	1	2	3	
…have a **very negative** impact on **the quality of nature and the environment**.	○	○	○	○	○	○	○	…have a **very positive** impact on **the quality of nature and the environment**.
…have a **very negative** consequences for **future generations**.	○	○	○	○	○	○	○	…have a **very positive** consequences for **future generations**.
…be **not effective at all** to limit global warming.	○	○	○	○	○	○	○	…be **very effective** to limit global warming.
…**strongly inhibit other efforts** to reduce CO_2 emissions (such as using more renewable energy, reducing fossil energy use).	○	○	○	○	○	○	○	…**strongly support other efforts** to reduce CO_2 emissions (such as using more renewable energy, reducing fossil energy use).

2. In general, I think the implementation of [afforestation and reforestation/DACCS] is…



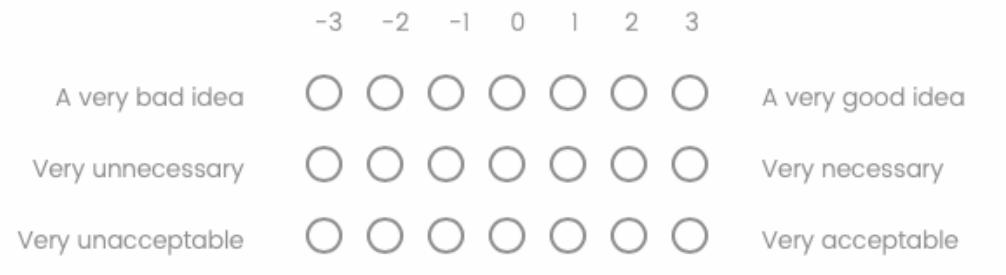
Part 4 - perceived fairness and acceptability of AR in a hypothetical country

Please imagine that the governments around the world have together agreed to remove CO_2 emissions via [afforestation and reforestation/DACCS]. The next question is which specific country should best implement it. We would like to know how appropriate you think it is to implement [afforestation and reforestation/DACCS] in the following country. Below, you will read the description of this country based on the scientific reports.

Description of the country
This country is one of **the highest CO_2 emitting countries** and has **sufficient knowledge and resources** to implement afforestation and reforestation.

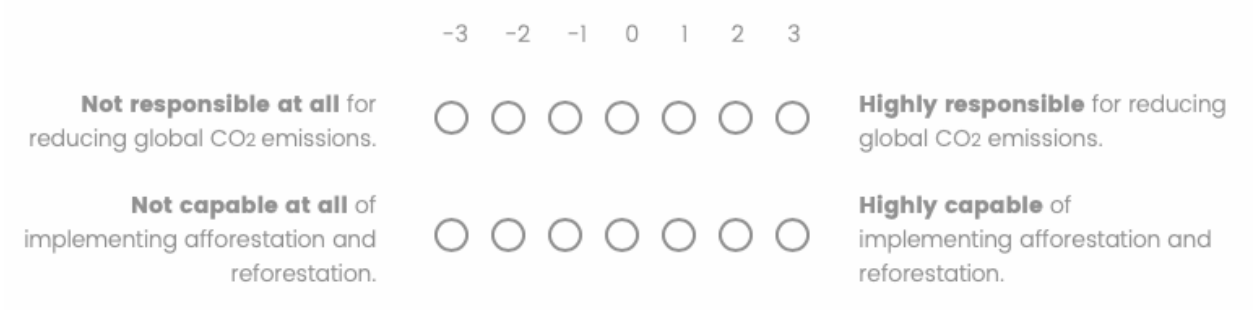
1. How fair do you think it is to ask this country to implement [afforestation and reforestation/DACCS]?

2. I think asking this country to implement [afforestation and reforestation/DACCS] is …



3. I think this country is …

*Note: the final item was adapted into “not capable at all/Highly capable of implementing DACCS” in DACCS condition.



Part 5 - Opinions about how to achieve climate goals

1. In your view, what percentage of CO_2 should be reduced by:

- switching to renewable energy;
- switching to nuclear energy;
- changing behaviour (such insulating homes, flying less and eating less meat);
- implementing negative emission technologies and practices (NETPs; such as afforestation and reforestation, or DACCS).

Please fill in the percentage that you think it should be reduced by each method. The total percentage should be 100%.

Switching to renewable energy	0 %
Switching to nuclear energy	0 %
Changing Behaviour	0 %
Implementing NETPs	0 %
Total	0 %

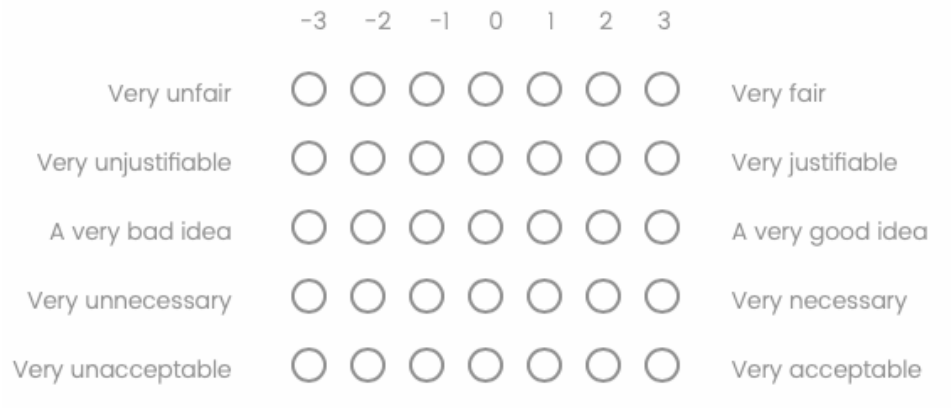
Part 6 - implementation of NETPs in your country

We are interested in how appropriate you think it is to implement afforestation and reforestation, or Direct Air Capture with Carbon Storage (DACCS) in your country. There are no right or wrong answers. Please indicate your personal opinion.

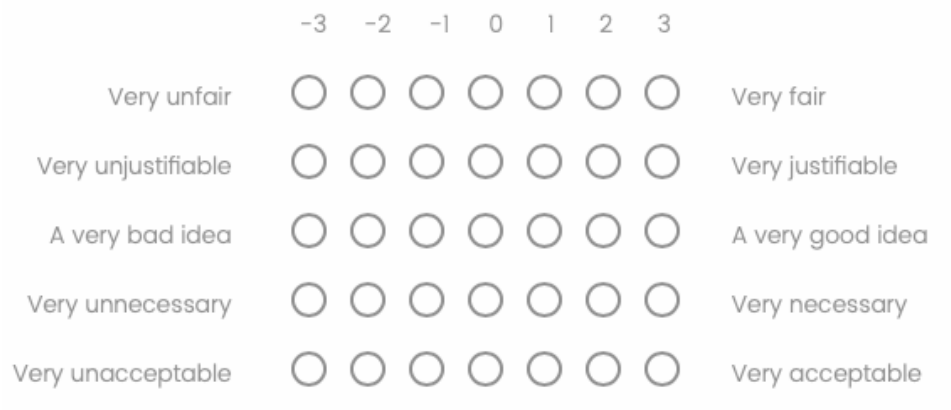
NEGEM

1. Compared to most other European countries, I think [country]...

2. I think asking [country] to implement afforestation and reforestation to help limit climate change is…



3. I think asking [country] to implement DACCS to help limit climate change is…



Part 7 - Opinions about public participation

We are interested in your opinions about involving the public in decision-making about negative emission technologies and practices (NETPs). There are different ways to involve the public in decision-making about the development of NETPs.

How desirable and necessary do you think it is to...

1. ...**inform** the public about the development of NETPs?

	-3	-2	-1	0	1	2	3	
not at all desirable	○	○	○	○	○	○	○	very desirable
not at all necessary	○	○	○	○	○	○	○	very necessary

2. ...let the public **express their opinion** about the development of NETPs?

	-3	-2	-1	0	1	2	3	
not at all desirable	○	○	○	○	○	○	○	very desirable
not at all necessary	○	○	○	○	○	○	○	very necessary

3. ...let the public **decide together with governments and experts** about the development of NETPs?

	-3	-2	-1	0	1	2	3	
not at all desirable	○	○	○	○	○	○	○	very desirable
not at all necessary	○	○	○	○	○	○	○	very necessary

4. ...let the **public themselves take decisions** about the development of NETPs?

	-3	-2	-1	0	1	2	3	
not at all desirable	○	○	○	○	○	○	○	very desirable
not at all necessary	○	○	○	○	○	○	○	very necessary